

E L E M E N T S
O F
N A T U R A L H I S T O R Y
A N D
C H E M I S T R Y.

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W I T H

An Alphabetical Comparative View of the Ancient and Modern
Names of CHEMICAL SUBSTANCES, with all the TABLES,
and a Complete INDEX.

To which is prefixed by the TRANSLATOR,

A PREFACE, containing Strictures on the History and present
State of CHEMISTRY; with Observations on the Positions,
Facts, and Arguments, urged for and against the ANTIPHLO-
GISTIC THEORY, and the NEW NOMENCLATURE, by
Messrs LAVOISIER, PRIESTLEY, KIRWAN, KEIR, SAGE, &c.

I N T H R E E V O L U M E S.

V O L. II.

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P A R T II.

C H A P. VIII.

Genus IV. *Neutral Salts, with a base of Magnesia, or
Magnesian Salts.*

WE have already seen in the history of acids, that magnesia naturally combines with those salts, forming by that combination a peculiar genus of neutral salts. Those neutral salts are as yet but imperfectly known, few chemists having made them the subject of their inquiries. The celebrated Dr Black first distinguished them as a peculiar genus of salts; they were before confounded with other neutral salts, having an earthy base.

Magnesian salts possess generic characteristics. Almost all of them are salt and bitter; and they may be obtained, though not without difficulty, in regular crystals. Most of them dissolve very readily in water, and

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some even attract the moisture of the atmosphere. They are easier decomposed than ammoniacal or calcareous salts : barytes, lime, the fixed alkalis, and even ammoniac in part, rob them of their acids. Ammoniac enters into union with both magnesia and an acid at the same time ; and thus forms ammoniaco-magnesian salts, consisting of three principles.

In this chapter we mean to examine six of those salts ; namely, magnesian sulphate or Epsom salt, magnesian nitrate, magnesian muriate, magnesian borate, magnesian fluuate, and magnesian carbonate.

Species I. *Sulphate of Magnesia, or Epsom Salt.*

THE neutral salt formed by the combination of the sulphuric acid with magnesia, has received the name of *Epsom salt*, from Epsom wells in England, where it was formerly obtained in great abundance. It is likewise found in the waters of Egra, Sedlitz, and Seydschutz. Its proper name is *sulphate of magnesia, or magnesian sulphate*.

This salt has a very bitter taste, from which it has been called *bitter cathartic salt*. In commerce it appears in small needles, terminating in very sharp pointed pyramids ; in which state it is pretty much like sulphate of soda, or *Glauber salt* : but it is of a more bitter taste, does not effloresce in the air, and when regularly crystallized, gives crystals of a very different form. When suffered to crystallize spontaneously, its crystals are fine quadrangular prisms, terminating in pyramids, which are also quadrangular. The sides of those prisms and pyramids are smooth and plain, and the crystals are generally shorter and thicker than those of sulphate of soda. All its other properties, as

we

we shall hereafter see, concur to distinguish it from that perfect neutral salt.

Sulphate of magnesia, like sulphate of soda and borax, retains in its crystals enough of water to make it susceptible of aqueous fusion. The most moderate heat is sufficient to melt it: when cooled after this fusion, it becomes a shapeless mass. If it remain exposed to fire after this aqueous liquefaction, it dries into a white friable mass, which is the salt unaltered, only without the water which entered into its crystals. A very intense heat is requisite to bring magnesian sulphate to an actual igneous fusion. This salt in crystals contains a quantity of water nearly equal to half its weight.

Macquer and several other chemists say, that when exposed to the air, it becomes somewhat moist, and that it may be distinguished by this property from sulphate of soda which effloresces. Bergman again informs us, that when magnesian sulphate is exposed to the atmosphere in a dry state, it immediately loses its transparency, and is at length reduced to a white powder: he adds, that the magnesian sulphate in small needles, which is commonly sold in the shops, owes its moist deliquescent appearance to the magnesian muriate which it contains. M. Butini, a citizen of Geneva, to whom we are indebted for a number of valuable experiments on magnesia, mentions his having found sulphate of soda, or Glauber salt, in English Epsom salt: and to this the efflorescence may be attributed. But pure sulphate of magnesia, though it loses its transparency in the air, is far from being so liable to efflorescence as sulphate of soda, which at the end of a certain time is entirely reduced to dust.

Sulphate of magnesia dissolves in water so readily, that rather less than two parts of cold water are sufficient

to maintain one part of this salt in solution; and warm water dissolves a quantity of it equal nearly to twice its own weight. It crystallizes by cooling; but in order to obtain it in very regular crystals, we leave the solution to crystallize when cold by spontaneous evaporation.

This salt suffers no alteration from either siliceous or aluminous earth.

Barytes decomposes it, having a greater affinity than magnesia with the sulphuric acid.

Lime, for the same reason, decomposes it. If a little sulphate of magnesia be poured into lime-water, or a certain quantity of lime-water be poured into a solution of this salt, a precipitate is produced, consisting of magnesia and calcareous sulphate. Recourse may be had at any time to the precipitation, as a sure criterion to enable us to distinguish magnesian sulphate from sulphate of soda.

The pure fixed alkalis likewise decompose sulphate of magnesia. Caustic ammoniac has the same influence on this salt; and as it does not decompose calcareous sulphate, we learn from these facts, that it has a stronger affinity with the sulphuric acid than magnesia, and a weaker than lime. Thus we gain a certain criterion by which we may distinguish when magnesian sulphate exists in water. In this manner, by the use of caustic ammoniac, pure magnesia, of which we gave the history in entering on the consideration of saline matters, may be obtained. Yet Bergman has observed, that ammoniac does not effect an entire precipitation of the magnesia of Epsom salt; part still remains unaltered. The liquor in which the two substances are mixed, maintains both ammoniacal and magnesian sulphate in solution at the same time. Chemists have discovered that these two salts join to form a third, consisting of an acid and the two bases. But to prevent mistakes,

mistakes, we must observe, that though these salts be found together in the same water, yet the one consists of ammoniac in combination with the sulphuric acid, while the other is a combination of magnesia with the same acid. Each possesses a distinct portion of the acid; both the bases are by no means in union with the same portion of the acid: yet these two sulphates have a pretty strong mutual affinity; they crystallize together, and thus produce what may be called a *triple salt*, or *ammoniaco-magnesian sulphate*.

We know not well in what manner magnesian sulphate affects those neutral salts which have for their base a fixed alkali or ammoniac: probably it would decompose the nitric and the muriatic salts with these bases by a double affinity.

M. Quatremere Dijonval asserts, in a letter to M. de Morveau, (*Journal de Physique*, May 1780, vol. xvii. page 391.), that when a solution of sulphate of magnesia is brought into contact with a solution of ammoniacal sulphate, the former salt is entirely precipitated without being decomposed: it falls to the bottom of the glass in large crystals, the taste of which indicates their nature. He ascribes this effect to the property which ammoniacal sulphate possesses, of attracting water from sulphate of magnesia, which he believes to crystallize very readily. But this is a mistake; for the salt crystallized on this occasion is a real triple salt, or ammoniaco-magnesian sulphate, as I know from unequivocal experiments.

The carbonic salts and magnesian sulphate mutually decompose each other. When a solution of carbonate of potash or soda is poured into a solution of magnesian sulphate, a double decomposition and a double combination take place. The sulphuric acid of Epsom salt combines

with the fixed alkali, and the carbonic acid separated from the alkali unites with the magnesia to form the neutral salt known by the name of *mild or effervescent magnesia*, and which we call *carbonate of magnesia*. The mild magnesia, used in medicine as an excellent purgative, is prepared in this manner. We will give a minute description of the process at the end of this chapter.

According to M. Dijonval, when a solution of sulphate of lime is mixed with a solution of sulphate of magnesia, the latter salt is precipitated: but the quantity of calcareous sulphate that can be maintained in solution is so small that this phenomenon is scarcely discernible. Calcareous nitrate and calcareous muriate likewise decompose sulphate of magnesia, and are decomposed by it in their turn: but we cannot think this fact warrants the conclusion which M. Dijonval deduces from it, namely, that the nitric and the muriatic acids have a greater affinity than the sulphuric acid with magnesia; for it is evident that double elective attraction acts in these instances.

Bergman says, that a quintal of sulphate of magnesia in crystals contains nineteen parts of pure magnesia, thirty-three of sulphuric acid, and forty-eight of water.

Sulphate of magnesia, or Epsom salt, is of considerable use in medicine. It is a good purgative, and acts at the same time as a discutient. It is even preferred to other purgative salts, on account of its extreme solubility. It is either given by itself, dissolved in water, in doses of from one to two ounces; or a dram or two of it is administered along with some other medicine. Most waters that are naturally purgative derive their mineral qualities from it, more especially those of

Egra

Egra, Sedlitz, and Seydschutz: but they likewise contain muriate of magnesia.

Species II. *Magnesian Nitrate.*

MAGNESIAN nitrate, which chemists have hitherto called *nitre of magnesia*, or *nitrated magnesia*, has been examined by Bergman. That illustrious chemist says, an artificial solution of this salt gives, after a proper evaporation, prismatic, quadrangular, and spathose crystals, without pyramids.

This salt has an acrid and very bitter taste; heat decomposes it; and it imbibes moisture in the air. It dissolves very readily in water; a slow evaporation is requisite to make it crystallize; and we are even so imperfectly acquainted with the laws of its crystallization, that we cannot make it assume a regular form at pleasure, like many of the other salts. Barytes, lime, and the alkalis, decompose it.

As magnesian nitrate is found dissolved in mother-water of nitre, M. de Morveau has proposed precipitation by lime-water, as a method of obtaining the magnesia in the great way. This process, being so cheap and easy, might be employed with great advantage; but as the same chemist has observed that fresh lime-water precipitates pure calcareous nitrate when it is dissolved in too scanty a proportion of water, the magnesia obtained by this process would not possess the degree of purity requisite to render it an useful medicine, unless the mother-water were diluted in a large quantity of common water.

The sulphuric and the fluoric acids disengage the acid from nitrate of magnesia. The boracic acid like-

wife separates it with the help of heat, in consequence of its fixity. These properties of this salt have been pointed out by Bergman.

M. Quatremere Dijonval, who has examined many of the combinations of magnesia, has found magnesian nitrate to possess some properties very different from those ascribed to it by the chemist of Upsal. He tells us, that he obtained crystals of magnesian nitrate, not liable to deliquium; and adds, that magnesian salts are not less disposed to crystallization and efflorescence than calcareous salts to attract moisture.

Nitrate of magnesia appears to be capable of decomposing sulphate of potash, soda, or ammoniac, by double affinity. But these decompositions are not so observable when solutions of the salts are mixed together, as the decompositions effected by calcareous nitrate; because the nitrates of potash, soda, or ammoniac, as well as the sulphate of magnesia, consequently produced, are all very soluble in water; whereas the sulphate of lime produced by the decomposition of sulphate of potash, soda, or ammoniac by calcareous nitrate, gives a very copious precipitate. By evaporating the liquors, however, we can make ourselves certain of the effects produced by magnesian nitrate on the above-mentioned salts. Nitrates are found to be formed by the union of the alkalis with the nitric acid, and sulphate of magnesia by the combination of sulphuric acid from the decomposed salts with the base of magnesian nitrate.

M. Dijonval mentions a fact which well deserves the attention of chemists. It is the precipitation of magnesian nitrate by calcareous nitrate. When pure transparent solutions of these two salts, says he, are mixed together, the magnesian nitrate is immediately deposited on the bottom of the vessel in a crystalline form,

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and not at all altered; but the calcareous nitrate remains dissolved in the liquor. It is very singular, that of two salts which will remain dissolved if they be kept separate, one is instantly precipitated in crystals when they are brought into contact with each other. M. Dijonval thinks, as we have mentioned above, that this depends on the strong tendency of calcareous nitrate to combine with water. This salt being, in his opinion, capable of absorbing a greater quantity of water than what is necessary to maintain it in solution: when mixed with a solution of magnesian nitrate, which has an equal tendency to crystallization, it robs this last salt even of the water of its crystals; and the magnesian nitrate then acquiring greater specific gravity, is precipitated in a crystalline form. There are, however, several difficulties not solved by this explanation. How can any salt, however great its tendency to solution, absorb the water belonging to the crystals of another salt, when it is itself already combined with a quantity of that liquid sufficient to maintain it in solution? If it be answered, that it is not saturated with water, there must then be a certain point of saturation, at which calcareous nitrate would cease to precipitate magnesian nitrate; and this should surely have been shown. But though this were granted, how could calcareous nitrate deprive magnesian nitrate of the water of its crystals, and yet suffer it to be precipitated in a crystalline form? Lastly, How is it possible that magnesian nitrate, after losing its water of crystallization, can be instantaneously precipitated in crystals? We are thus induced to think that some particulars must have escaped M. Dijonval's observation; and that the true cause of this phenomenon is not likely to be discovered till such time as the experiment has been again and again repeated with various quantities

tities of water, and of the salts, as well as in various temperatures, &c.

Magnesian nitrate is not applied to any use either in the arts or in medicine. Its strong taste, its tendency to deliquiate, and indeed all its properties, lead us to think, that it would act powerfully on the animal œconomy; and it is much to be wished that it were tried as a diffolvent and incisive in all cases in which medicines of that nature are requisite.

Species III. *Magnesian Muriate.*

THIS salt, which is a saturated combination of the muriatic acid with magnesia, exists in all salt waters, and in all waters containing magnesian fulphate in a state of solution; such as those of Epfom, Egra, Sedlitz, and Seydschutz, as well as many others. It is much more common than it was once thought to be.

Magnesian muriate has a very bitter hot taste. Bergman says, that the only way of obtaining it in crystals is by exposing a solution of it, highly concentrated by evaporation, to a sudden and extreme cold. It is then obtained in the form of small needles, having a strong tendency to deliquiate. The solution is commonly a transparent jelly: But M. Dijonval says, that he obtained this salt in a regular permanent form; and that it has a tendency rather to effloresce than to deliquiate.

Magnesian muriate is decomposed and deprived of its acid by the action of fire. It is very difficult to drive off the last remains of the acid: after this operation the magnesia becomes caustic.

When this salt is exposed to the air, it appears to attract

tract moisture eagerly, and is soon dissolved into a liquid. Bergman and several other chemists have taken notice of its possessing this property. M. Dijonval, however, says, that magnesian muriate, like magnesian nitrate, rather effloresces than attracts moisture. But this assertion needs farther confirmation by experiment.

Magnesian muriate dissolves very readily in water; it even appears, that a portion of the fluid equal to itself in weight is sufficient to maintain any quantity of this salt in solution. It is very difficult to obtain this salt in regular crystals. Evaporation by heat succeeds very ill; for it concentrates the liquor too much; which, when cooled, assumes almost always the consistency of a jelly. Spontaneous evaporation in a summer temperature is more likely to crystallize this salt: but even this method is attended with great difficulties.

Muriate of magnesia, heated in a retort with siliceous earth and clay, gives out its acid; but as the action of fire alone is sufficient to produce this effect, it is not to be attributed to the earths.

Barytes and lime decompose this salt by precipitating the magnesia. As the mother-waters of muriate of soda in salt springs contain muriate of magnesia mixed with calcareous muriate, the magnesia which these salts contain may be precipitated in the great way, and at a small expence, by means of lime-water.

The fixed alkalis and caustic ammoniac have a greater affinity than magnesia with the muriatic acid, and cause the base of magnesian muriate to precipitate. The muriate of potash, soda, or ammoniac, according as the one or the other of these salts has been employed, remains dissolved in the liquor. Ammoniac does
not

not entirely decompose this salt, but forms a triple crystallizable muriatic salt with the remaining portion of it.

The sulphuric and the nitric acids decompose this salt, separating the muriatic acid with effervescence. In order to effect these decompositions, a mixture, consisting of one part of either of these acids and two parts of muriate of magnesia, is to be distilled in a glass retort. The acid belonging to the magnesian muriate is volatilized, while the other acids being stronger, combine with the magnesia to form magnesian sulphate or nitrate. The boracic acid likewise disengages the muriatic acid with the help of heat.

Magnesian muriate decomposes sulphuric and nitric salts, with a base of fixed alkali or ammoniac, by the way of double affinity. But in order to render these decompositions apparent, the solutions of the salts must first be poured upon a solution of magnesian muriate, and then evaporated, or mixed with spirit of wine; for the new saline matters formed by the decomposition remain dissolved in the water after it is effected.

When muriate of magnesia is brought into contact with muriate of potash, and both are in a state of solution, the former salt is precipitated in crystals, according to M. Dijonval, in consequence of its having a much greater tendency to crystallization than the other; which takes possession of the water by which it was maintained in solution. But it is difficult to conceive how any salt which has so small a tendency as muriate of potash to dissolve or deliquesce, can rob another salt, so soluble as magnesian muriate, of the water by which it was dissolved. The same chemist informs us, that when a solution of magnesian muriate is mixed with a solution of calcareous muriate, the former salt is precipitated in crystals. But farther experiments
are

are necessary to give these assertions such authority as may intitle them to rank among the elements of the chemical science. Very likely the crystals precipitated are not pure, but to be referred to the class of triple salts.

Magnesian muriate is not applied to any use: but, in my opinion, it might be very happily used in medicine as a purgative and dissolvent. Physicians always administer small quantities of it when they prescribe Epsom or Sedlitz waters, or grey marine salt; for those substances still contain more or less of it.

Species IV. *Magnesian Borate.*

THIS name is given to the combination of the boracic acid with magnesia. This salt is scarce known. Bergman has observed, that when a portion of magnesia is cast into a solution of the boracic acid it is slowly dissolved. This liquor, when evaporated, affords granulated crystals of an irregular form.

Fire melts, but does not decompose this salt. The acids decompose it by attracting the magnesia, and separating the boracic acid. Spirit of wine likewise carries off the acid, leaving the magnesia by itself. It appears therefore that magnesia does not adhere very closely to the acid of borax.

We must therefore confess ourselves to be very little acquainted with the properties of this salt, as chemists have made but very few experiments upon it.

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Species V. *Magnesian Fluatē.*

MAGNESIA in combination with the fluoric acid receives the name of *magnesian fluatē*, and is not better known than magnesian borate. Bergman is the only chemist who has said any thing of it. According to him, the fluoric acid dissolves magnesia very quickly; and when the acid is nearly saturated, a great part of the new-formed salt is precipitated.

The solution affords, by spontaneous evaporation, a kind of transparent froth which hangs to the sides of the vessel, consisting partly of long and very fine crystalline threads. There are at the same time obtained, in the bottom of the vessel, spathose crystals in hexagonal prisms, terminating in a short pyramid consisting of three rhombs. This salt is liable to no alteration from even the most extreme violence of fire. No acid has strength to decompose it in the humid way. This neutral fluoric salt, to which Bergman has attributed such extraordinary properties, is well worthy of a more particular examination.

Species VI. *Magnesian Carbonate.*

THIS salt, to which Dr Black, the first discoverer of it, has given the name of *mild or effervescent magnesia*, is formed, as the name we have given it indicates, by a saturated combination of magnesia with the carbonic acid. It is commonly prepared by precipitating a solution of magnesian sulphate with carbonate of potash or soda, in a way which we shall describe at the end of this article.

Magnesian carbonate has most generally an earthy appearance:

appearance: it is in the form of a very white powder. Yet Bergman and M. Butini of Geneva obtained it in crystals by the process which we are hereafter to describe. Like all other carbonic salts, it may contain either a greater or a less proportion of the acid; and its properties vary according to the proportion in which the acid exists in it. Its taste is crude and earthy. But it affects the intestines in a more sensible manner; for it is purgative.

This salt, when exposed to fire in a crucible, loses both the water and the acid which it contains. M. Tingry apothecary at Geneva, has observed, that when effervescing magnesia is calcined in the great way, it bubbles, and exhibits on its surface the motion of a fluid. This phenomenon is owing to the disengagement of the acid gas. There arises out of the crucible a thin vapour, which deposits on contiguous bodies a white dust that is readily known to be magnesia carried off by the current of the carbonic acid. If a warm body be immersed in the crucible, the salt adheres to it; a cold body attracts still more. Towards the end of the operation, the magnesia displays a bluish phosphoric light, which in the dark is very discernible.

By calcining carbonate of magnesia in close vessels, with a pneumato-chemical apparatus, we obtain water and the acid of the salt. M. Butini, who performed this operation in a very exact manner, informs us, from a calculation founded on the products which he obtained, that thirty-two grains of common magnesia (what he calls *common magnesia* is a kind of magnesian carbonate prepared for pharmaceutical purposes, and not completely saturated with the acid) consist of about thirteen grains of pure earth, twelve of the acid, and

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seven of water. Bergman reckons a quintal of this salt to contain twenty-five or thirty parts of the acid, according to its particular state, thirty of water, and forty-five of pure magnesia. If exposed to a more intense heat, after losing its acid it is agglutinated and becomes hard, like pure or caustic magnesia.

Magnesian carbonate suffers no very remarkable alteration from air; yet, when exposed to a damp atmosphere, it assumes the form of little clods, and appears to deliquiate in some degree.

Water dissolves but a very small proportion of this salt; and its solubility in water varies, according as it contains more or less of the acid. When a quantity of the salt is mixed with a small portion of water, it composes a kind of paste; which, however, is not very tenacious, and dries up without acquiring consistency or shrinking into a smaller bulk. If diluted in a very large proportion of water, magnesian carbonate dissolves gradually, at the rate of a quarter of a grain of the salt to an ounce of the fluid; as appears when the liquor is evaporated. But there are ways of making this salt dissolve in a much larger proportion; which we will immediately mention.

Pure earths do not decompose carbonate of magnesia. Lime robs it of its acid. Lime-water poured into a solution of this salt, occasions an observable precipitation, however small the quantity of the neutral salt dissolved in the water. The precipitate consists of carbonate of lime, and a little caustic magnesia, which is known to be almost insoluble.

The fixed alkalis and caustic ammoniac likewise decompose this salt: for they, as well as lime, have a greater affinity than magnesia with the carbonic acid. The results of these mixtures are carbonate of potash,

soda, or ammoniac, and pure caustic magnesia,—which is precipitated.

The sulphuric, the nitric, and the muriatic acids, decompose magnesian carbonate in a directly contrary way, and by that means complete the analysis of this neutral salt. They unite with the magnesia, with which they have a stronger affinity than the carbonic; and they occasion an effervescence by disengaging that acid under a gaseous form. The carbonic acid which escapes on the occasion is distinguished by its usual characteristics. M. Butini observed, in his experiments, that it was rather the fire than the acids which disengaged the carbonic acid; and that each of those salts separated a different quantity. Thus, for instance, he found the muriatic acid to disengage more than the nitric, and the nitric more than the carbonic. From these facts he concluded, that neutral salts, consisting of magnesia in combination with an acid, namely sulphate and nitrate of magnesia, still retain a portion of the carbonic acid.

The carbonic acid possesses the property of rendering carbonate of magnesia much more soluble than the pure saline-terreous matter. M. Butini's late experiments have been chiefly directed to determine the phenomena of this solution. He has discovered, that when any quantity of common magnesia, not saturated with the carbonic acid, is thrown into water in a gaseous state, or impregnated with the acid, the magnesia immediately absorbs as much acid from the water as is requisite to saturate it, and even does not dissolve till it be super-saturated. This solution communicates a green tincture to syrup of violets. When exposed to cold, it loses its excess of acid; but the magnesia is not separated from the water, even though

it be frozen into ice. When a solution of magnesia, super-saturated with carbonic acid, is exposed to heat, it loses its transparency, but regains it when suffered to cool. This singular phænomenon offers to our observation, as M. Butini has very well observed, a new kind of salts, to which it is peculiar to dissolve in a larger proportion in cold than in hot water. The more magnesia any gaseous solution contains, the sooner does it lose its transparency by heat. In order to have a proper opportunity of observing how this salt, from muddy, becomes transparent as it cools, the above mentioned chemist directs us to take a solution, containing two grains of magnesia to an ounce of water, and to heat it to 170° of Fahrenheit's thermometer. Heat gives it a milky consistency; but all the magnesia now precipitated is again dissolved by cold.

Bergman had before observed, that when a solution of magnesia impregnated with carbonic acid was slowly evaporated, it afforded crystals, some of which were in transparent grains, others resembled two pencils of rays diverging from one point. M. Butini has observed all the phænomena of that crystallization with greater accuracy. With the heat of a lamp which was very faint, he evaporated a solution containing nine grains of this salt to the ounce of water. A pellicle was soon formed on the surface, the under part of which, as well as the sides of the vessel, was in a manner fringed over with bunches of crystals. The residue exhibited bright needles, consisting of small hemispherical masses with diverging threads. These needles were not a line in length; but when viewed with a microscope, appeared to be long prisms with
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fix sides, truncated by an hexagon, and resembling some spars.

M. Butini has likewise discovered another way of crystallizing magnesian carbonate. It consists in exposing to the air a solution of this salt precipitated by heat. At the end of a few days, this solution affords crystals resembling those which are obtained by evaporation. Magnesia precipitated from Epsom salt by carbonate of potash, and afterwards dried, will not crystallize in this manner: though diluted in water, it never forms any other than irregular lumps. But a solution of sulphate of magnesia, taken soon after it has been precipitated by the same salt, gives, at the end of several days, crystals in the shape of needles. When this solution is separated by filtration from its precipitate, it likewise gives needles of magnesia. I have often observed, that a solution of carbonate of magnesia, prepared for the use of a laboratory, and kept in well stoppered glass phials, deposits, after some time, a large quantity of very fine bright small needles, which, when viewed through a magnifier, appear to be prisms of six sides.

Perfect neutral salts suffer no alteration from magnesian carbonates, nor do they produce any change upon it. Only, according to M. Butini, they render it more soluble in water. But carbonate of potash must here be excepted; for it rather destroys *its* solubility.

Effervescent magnesia decomposes calcareous neutral salts; and this decomposition is effected by virtue of a double affinity. We have already observed that lime has a greater affinity than magnesia with the acids, and of consequence decomposes neutral salts, which

have magnesia for their base. It is to the acid, therefore, that the decomposition of calcareous salts by magnesian carbonate is owing. Lime, on account of the strong affinity which it has with the carbonic acid, forsakes the other acids to combine with it, provided the acids which it deserts find another base with which they can enter into combination. Therefore, when a solution of magnesian carbonate is poured into a solution of calcareous sulphate, nitrate, or muriate, the sulphuric, the nitric, or the muriatic acid, forsaking the lime, combines with the magnesia to form sulphate, nitrate, or muriate of magnesia; while the lime combining with the carbonic acid separated from the magnesia is precipitated in chalk.

Magnesia in this instance, therefore, resembles ammoniac. When either of these substances is pure and caustic, it is incapable of decomposing calcareous salts, as having a greater affinity than lime with the acids. But when united with the carbonic acid, and in the state of neutral salts, they then acquire the power of decomposing calcareous salts by double attraction; as has been already shown under the articles Sulphate of Lime, Calcareous Nitrate, &c.

The salt of which we are speaking is used in medicine under the name of *mild or white magnesia*. It was formerly prepared from mother water of nitre, evaporated to dryness, or precipitated by fixed alkali. It was originally known by the name of *Count Palma's powder*, and *Sentinelli's powder*: It has since been called *laxative polychrest salt* by *Valentini*, *white magnesia of nitre*, *magnesia of common salt*; because it was obtained from the mother water of this last salt. But when prepared in this manner, it always contains calcareous

careous earth, and various other extraneous matters: And therefore, what is at present made use of, is usually precipitated from sulphate of magnesia by vegetable fixed alkali, or carbonate of potash.

M. Butini gives an excellent process for obtaining it very fine and in as large a quantity as possible. Dilute any quantity of potash in twice its weight of cold water: let this lixivium, if the season will allow, be exposed to the air for some months, in order that it may absorb carbonic acid from the atmosphere, and the earth which it contains may be precipitated: let it then be filtrated: next dissolve a quantity of sulphate of magnesia equal to the quantity of potash which you have already dissolved, in water equal to four or five times its weight: filtrate this solution, and add a new quantity of water equal to five times the weight of the salt. Let this liquor be heated to ebullition, and then poured into the solution of vegetable alkali. The precipitate of magnesia is soon formed, and the mixture must then be well stirred, and afterwards filtrated through paper. The precipitate which remains on the paper used in the filtration must be washed with boiling water, to carry off the sulphate of potash intermixed with it. After the water is sufficiently drained off, the magnesia must be taken and spread on pieces of paper in thin layers, and put into a stove to dry. When thoroughly dried, it appears in the form of white lumps, which crumble between the fingers into a very fine powder that sticks to the skin.

This magnesia, in combination with the carbonic acid, is to be preferred as a purgative; because it is much more soluble. It is given in doses of one or of two ounces, as the case requires. But caustic magne-

sia again is preferable to it as an absorbent ; and apothecaries should keep both kinds. The principal reason for preferring sometimes the one, sometimes the other of these, in the practice of physic, on account of which apothecaries ought always to keep both kinds, has been very well explained by Macquer in a paper inserted among those of the Royal Society of Medicine. When magnesia is given as an absorbent, the design of it is to destroy and neutralize an acid existing in too great abundance in the primary passages, as is the case with children, young girls, lying-in women, &c. That gastric acid is certainly stronger than the carbonic. When mild magnesia, therefore, enters the stomach, it produces an effervescence, more or less lively according as there is more or less of the acid to be absorbed in the primary passages. The carbonic acid disengaged by that effervescence, distends the stomach, and frequently occasions pains, nausea, vomitings, a difficulty of breathing, with many other spasmodic complaints, according as the sensibility of the parts is greater or less. In such cases, therefore, it is much better to make use of pure magnesia, which absorbs the four matter as powerfully, and occasions no effervescence.

Again, when magnesia is given as a purgative, and not to absorb acid matter in the primary passages, magnesian carbonate may then be given. The carbonic acid is not disengaged in this case, and the complaints occasioned by this elastic fluid distending the stomach are not to be feared. Physicians ought therefore to be acquainted with these two kinds of magnesia, and to know when the one and when the other is to be administered ; and apothecaries ought always to keep both in their shops.

M. Butini mentions an artificial mineral water, consisting

filling of gaseous water impregnated with magnesia. He observes, that this fluid may be made to contain three drams of this magnesian earth to the pound; and that, besides, it may be as easily prepared as acidulated or gaseous martial waters. In fact, both are prepared precisely in the same way. Physicians might find this water useful on many occasions.

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C H A P:

CHAP. IX.

Genus V. *Argillaceous or Aluminous Neutral Salts.*

CLAY, or aluminous earth, when very pure, combines very readily with most of the acids. From those combinations there result neutral salts, which are known by the general name of *argillaceous* or *aluminous salts*. Excepting the first species, no part of this genus of saline matters has yet been examined with proper care by chemists. And their properties are therefore still less known than the properties of the salts belonging to the four preceding genera. Aluminous salts are in general more imperfect than any of the neutral salts which have hitherto engaged our attention. They yield their acids to the fixed alkalis, ammoniac, barytes, lime, and magnesia. They have a sour astringent taste.

This genus includes six species;—alum, or aluminous sulphate; aluminous nitrate; aluminous muriate; aluminous borate; aluminous fluuate; and aluminous carbonate.

Species

Species I. *Aluminous Sulphate or Alum.*

ALUM is a neutral salt, consisting of the sulphuric acid combined with aluminous earth or pure clay, and it merits, of consequence, the name of *aluminous sulphate*. Chemists have not been always agreed concerning the nature of the base of alum. Some formerly distinguished it from clay, under the name of *aluminous earth* or *earth of alum*. Margraaf has shown that a mixture of this earth with filix, both in powder, forms clay. Hellot, Geoffroy, Pott, and more especially M. Baumé, have all formed genuine alum by mixing clay with the sulphuric acid. Lastly, if the characteristic properties of clay be to form a tenacious paste with water, and to shrink and harden when exposed to fire; as aluminous earth displays these properties in an eminent degree, it is therefore to be considered as the purest part of clay. Such is the opinion which at present is generally prevalent among chemists concerning this matter. This shows still more strongly the propriety of distinguishing the earth which serves as the base of alum by the peculiar name of *aluminous earth*; because clay, however pure, always contains a portion of siliceous earth.

Aluminous sulphate, or alum, at first affects the organs with a sweetish taste, and is afterwards felt to be strongly astringent. It makes blue paper red; which shows it to contain a portion of unsaturated acid. It is capable of a very regular form, which will be described below.

Alum is scarce ever found in nature in a pure insulated state. Sometimes, however, it is found in places near

near volcanoes, but always mixed with clay. Mineralogists, particularly Wallerius, have taken notice of several species of native alum; such as solid alum, crystallized alum, alum in an efflorescence, white, grey, brown, and black, aluminous earths, and aluminous schisti.

In commerce there are several kinds of alum known.

1. Ice or rock alum, in pretty large transparent masses. Bergman imagines it to derive this name from the city of Rocca in Syria, now called *Edeffa*, in which the earliest manufactory of this salt was established; not, as some writers would persuade us, from its resembling a rock, or from its being obtained from rocks: Alum obtained in this last way is very impure.

2. Roman alum, which is prepared in the territory of Civita-Vecchia, and obtained from a place the Italian name of which is *Aluminiere della Tolfa*. This alum is in lumps of the size of eggs, and covered over with a reddish efflorescence. It passes for pure when separated from the efflorescence.

3. Neapolitan alum, which is extracted at Solfatara from a particular earth. This alum is in larger lumps than the Roman, and one of its surfaces is covered all over with pyramidal crystals.

4. Alum of Smyrna. The earliest manufactories of alum appear to have been established in the neighbourhood of Smyrna and Constantinople. Some specimens of it are shown in the cabinets of the curious.

5. French alum. Alum of all sizes is prepared by various manufacturers in France, especially at Javel near Paris.

6. Alum may be extracted from efflorescent schisti and volcanic products. I have obtained it in a pretty large
large

large proportion from earth that was brought me from Auvergne. This salt might be obtained from other substances of the same kind that are to be found in France; and this branch of trade might be thus taken out of the hands of strangers. Alum is likewise extracted from earths and stones, which are found to contain it in many parts of Germany,—in which it has been manufactured since the year 1544, in Spain, in England, in Sweden, and in almost all the countries of Europe.

Beckman, in a dissertation on the subject, inserted among the acts of Gottingen, enters very fully into the history of this salt, and the method of manufacturing it. It appears from his learned researches, that the people of the east were the first who prepared or extracted alum; for what the ancients, and particularly Pliny, called *chiton*, *trichites*, *calchites*, and which they appear to have confounded with alum, as well as the *σουλφία* of the Greeks, seems to have been rather martial sulphate or green copperas in various states. The Italians took a lease of the alum manufactories in the neighbourhood of Constantinople. About the year 1459, Bartholomew Perdix, or Pernix, discovered a mine of this salt in the Isle of Ischia. Nearly about the same time, John de Castro found another at Tolfa, and a great number of alum manufactories were soon established in Italy, more especially when Pope Pius II. prohibited the importation of alum from the east. The manufacture passed next into Spain, Germany, England, and Sweden, about the beginning of the seventeenth century, (V. Beckman).

Aluminous sulphate is prepared by a variety of processes, according to the country where it is manufactured, and the materials from which it is obtained.

Bergman,

Bergman, who has written an excellent dissertation on the subject, divides the matters used in preparing alum, and commonly known under the name of *alum ores*, into two kinds: those in which this salt exists fully formed, and those which contain only its constituent principles. No farther process than a lixiviation is requisite to extract the alum from the first; and of this kind are the earth from which it is obtained at Solfaterra, and that which I have mentioned from Auvergne. At Solfaterra this earth is mixed with water, and put into caldrons of lead, partly sunk in the ground. The natural heat of the earth contributes to the solution and crystallization of the alum; and it is purified by a second crystallization. In the same manner might the earths of Auvergne, &c. be lixiviated, the water evaporated in leaden vessels, and the alum crystallized.

As to the natural substances which contain only the principles of aluminous sulphate, these are much more common than the former; and a preliminary preparation is requisite before a neutral salt can be obtained from them. Aluminous schists must be calcined, in order that the bitumen from which they derive their colour may be burnt, and that the pyrite part of the stone, which supplies the alum, may be decomposed. Bergman asserts, that if this schistus be washed before being calcined, it gives not a particle of alum. Exposure to the air produces the same effects on pure pyrites sprinkled with water. The spontaneous decomposition of these substances affords sulphuric acid, which combines with the clay to form alum. Those pyritous substances, when brought into a state of efflorescence, are lixiviated with water; and after being suffered to deposit the iron which it contains, the lixivium

vium is evaporated and put into casks to crystallize. The salt falls to the bottom in large crystals. A strong soapy lixivium is often made use of to facilitate the crystallization of the alum. This process is followed in several manufactories: But alum obtained in this manner always contains more or less iron. That again which is extracted from stones in which it exists ready formed is always purer, such as Roman alum, for instance. Alum manufactured by a direct combination of the sulphuric acid with clay is always mixed with a certain proportion of iron, as the coloured clay from which it is prepared is always impregnated with that metal.

Aluminous sulphate in a regular crystalline form is a perfect octohædron, consisting of two tetrahædral pyramids, with their bases united. This form, however, varies according to the circumstances of the crystallization; the octohædron is more or less truncated, irregular, pointed, or flattened. The angles are more or less complete, or cut away: the crystals are joined, and often enclaved in each other by means of their pyramids. M. Romé de Lille has very carefully described all of these varieties in the new edition of his Crystallography.

A gentle heat liquefies this salt: a good deal of aqueous vapour then exhales from it; and it swells into a large light mass, rough, and full of cavities, all over its surface. Here, as well as in the instance of borate, this phenomenon is owing to the disengagement of the water, the bubbles of which gradually raise and dilate the saline particles. Alum in this state receives the name of *calcined alum*. It has lost under the operation about half its weight. It is now somewhat altered, and reddens syrup of violets: its

its taste is stronger, the acid not being so much in a latent state as before. When dissolved in water, it gives as a precipitate a small portion of earth. It may be caused to crystallize; but it scarce swells at all when calcined anew, as M. Baumé has observed. By calcining alum in a machine for distillation, we obtain, first phlegm, and afterwards towards the end of the operation the acid. But we cannot decompose it entirely; for Geoffroy exposed a quantity of alum in a retort to a very intense fire during three days and three nights, without observing it to suffer any remarkable alteration. I am of opinion, however, that the changes which alum undergoes when long exposed to the action of fire, have not yet been examined with sufficient care.

Aluminous sulphate effloresces slightly, and loses the water of its crystals when exposed to the air. In cold water it is scarce soluble; for according to M. Baumé, two pounds of cold water dissolve no more than fourteen drams of alum: but boiling water dissolves a quantity equal to more than half its own weight. Eight ounces of the fluid in this state are sufficient to maintain five ounces of the salt in solution. It crystallizes readily by cooling. Its crystals seem to be a kind of triangular pyramids, with truncated angles, but are in reality pieces of octohædrons. Deposited on threads in the middle of the solution, they form very regular octohædrons, whose pyramids are obliquely truncated.

Siliceous earth effects no discernible alteration on aluminous sulphate. This salt may be made to unite with a larger quantity of aluminous earth than it ordinarily contains. M. Baumé has found by experiments, that on such an occasion it acquires the characteristic pro-

properties of common clay. To saturate alum with aluminous earth, a solution of the salt must be boiled with a portion of the earth pure, and the mixture heated till it lose its stiptic taste. If the combination be properly effected, it now acquires a mild, insipid, earthy taste. M. Baumé has observed, that when evaporated, it affords spangles resembling mica. The Duke de Chaulnes having left a lixivium of this salt saturated with earth, exposed for a considerable time to the air, found it to contain at the end of a few months very regular cubic crystals. M. le Blanc likewise obtained this substance in cubic crystals by a similar process. It appears that alum once saturated with earth can never be reduced to the state of pure alum.

Aluminous sulphate may be decomposed by barytes or magnesia, each of which has a greater affinity than aluminous earth with the sulphuric acid. Barytic, or magnesian sulphate, is the result of such a decomposition.

Lime-water poured into a solution of this salt precipitates the earth. Both the fixed alkalis and ammoniac decompose alum. Carbonate of potash, soda, ammoniac, lime, or magnesia, likewise separates the aluminous earth from this salt; but if the precipitation be effected without heat, the precipitated earth seizes part of the carbonic acid. But I have observed, that when a solution of alum is mixed with a hot solution of any of the alkaline carbonates, the precipitation is attended with an effervescence, owing to the disengagement of the carbonic acid.

Aluminous earth, when precipitated by any of these substances, subsides gradually and in flakes. If dried slowly, it becomes very white; when exposed to fire, it de-

crepitates like clays. A strong heat renders it pretty hard : its bulk is at the same time greatly contracted. It does not melt, though exposed even to so intense an heat as that of the burning-glass in the garden *de l'Infante*. So tenaciously does it retain its water, that the utmost force of fire is requisite to separate it entirely. With water it may be baked into a clammy paste, that makes, when burnt, excellent porcelain. Aluminous earth possesses therefore all the distinguishing properties of argillaceous earths, and Macquer has very justly declared it to be the purest clay that can be procured.

We know not very well in what manner barytes, magnesia, lime, and the pure alkalis, act on aluminous earth. Probably these substances, especially the last of them, would, with the help of fire, reduce it to a vitreous frit. M. Achard has made a series of experiments which verify this conjecture. The colour, the transparency, the hardness, and indeed all the properties of those substances, vary according to the proportions in which the principles of which they are formed have been mixed together ; as we learn from a dissertation by the above-mentioned chemist on the subject.

The sulphuric acid readily dissolves aluminous earth when it is cool and wet ; but when dry, it dissolves it not without considerable difficulty. Several ounces of this solution, taken together, afford crystals of alum, mixed with a few scales or spangles resembling mica. And M. Baumé tells us, that when this experiment is performed in the small way, only these scales, and no alum, are obtained. Other acids likewise dissolve this earth, forming with it salts which are but little known,

known, but shall be mentioned in some following articles.

We know not how aluminous earth would act upon the neutral salts: but its most singular property is that of combining in an extraordinary proportion with aluminous sulphate without communicating to it new properties; of which we have spoken above. M. Baumé, to whom we owe that discovery, boiled a solution of alum with a quantity of earth precipitated from this salt by one of the fixed alkalis; and the liquor dissolved the earth with effervescence. When filtrated, it had no longer the taste of alum, but tasted as hard water. It did not communicate a red colour to the tincture of turnsol, but it gave a green colour to syrup of violets. By spontaneous evaporation, it afforded a few crystals in soft scales resembling mica. M. Baumé compares them to selenite, or sulphate of lime. It is by no means easy to form alum by adding vitriolic acid to the salt thus saturated with earth; the mixture is now acid, but not stiptic: yet, by a spontaneous evaporation for three months, the solution afforded crystals of alum, mixed with some micaceous spangles, like those which alum saturated with earth afforded. Such is the result of the experiments of Messrs Macquer and Baumé on aluminous earth.

Alum, when exposed to fire with combustible matters, forms a substance which kindles in the air, and is called *Homberg's phosphorus*. That chemist, who made this combination known to the world in the year 1711, long laboured to obtain from the human feces a white oil, which he expected to fix mercury into fine silver. His labours on this project gave rise to several discoveries. The residue of that animal matter distilled with alum takes fire in the air. Homberg repeated

peated this process again and again, and it always succeeded. Lemery the younger, published in the year 1714 and 1715, two Memoirs, in which he informed the world that pyrophorus might be composed out of a great many vegetable and animal matters, treated with alum: but he did not succeed in forming it from some other sulphuric salts. Those two chemists, who considered alum as a combination of the sulphuric acid with calcareous earth, thought that the calcareous earth, being reduced to the state of lime, attracted moisture from the air; and that the sulphur, which they knew to be then formed, was inflamed by the heat then produced in the mixture.

Since the time of those chemists, Jay de Suvigny, doctor in medicine, has given an excellent memoir on this phosphorus, inserted in the third volume of the *Memoires des Savans Etrangers*. In that paper he details a great many experiments, by which he at length effected the composition of phosphorus, not only from alum with various combustible matters, which Lemery had effected, but even from most salts containing sulphuric acid. That Chemist has likewise given a theory of the inflammation of phosphorus when exposed to the air, which has been unanimously adopted by later chemists. He takes pyrophorus to contain *glacial oil of vitriol*, which by attracting moisture from the air, and gradually heating the mass, kindles the sulphur, and occasions a spontaneous evaporation.

Pyrophorus is usually prepared by melting three parts of alum with one of sugar, honey, or meal, in an iron ladle. This mixture is dried till it become blackish and cease to swell. It is then broken into pieces, and put into a matrafs, or phial luted with earth; this vessel is then put into a crucible containing sand, and heat is applied

applied till a bluish flame be seen to issue from the mouth of the phial. After suffering it to burn in this manner for a few minutes, the crucible is removed from the fire. Its contents are left to cool, and the pyrophorus is then poured into a dry flask, which admits of being very closely stopped. This pyrophorus takes fire on being exposed to the air; and that the more readily in proportion as the atmosphere contains a greater quantity of aqueous vapour. Its combustion may be accelerated by bringing it into contact with humid vapour, such as the human breath. Pyrophorus, if too long exposed to heat when it is composed, becomes incapable of taking fire in the air. When kept in a vessel not closely stopped, it is gradually impregnated with moisture, and loses its tendency to combustion: but it may be reduced by calcining it anew, in the manner above described.

This was all that we knew of phosphorus, before M. Proust's valuable experiments, of which he has given an account in the *Journal de Medicine* for July 1778. That chemist, in the course of his chemical operations, having met with a great number of pyrophoric residues, which he could not well suppose to contain any portion of sulphuric acid, was induced to think that pyrophorus did not owe to that acid its spontaneous inflammation. By a very simple experiment, he has proved that it does not contain a single particle of sulphuric acid not in a latent state; for when water is poured on it, no heat is produced. The result of all his experiments and observations on this head is, that all substances which leave, on being decomposed, a carbonaceous residue intermixed with an earth or a metallic oxide, are capable of spontaneous inflammation in the air. Yet we cannot avoid observing, that M. Proust, in that part of his researches on this matter which he has communicated to the public,

does not explain the reason why Homberg's pyrophorus takes fire in the air; for according to him, it is a substance entirely different from those of which he gives an account. His memoir, indeed, says nothing at all of the pyrophorus which we have described above.

Mr Bewly, an English surgeon, in a letter addressed to Dr Priestley, ascribes the inflammation of pyrophorus to its containing a substance capable of attracting nitric acid from the atmosphere. What suggested this opinion to him was his discovering that spirit of nitre instantly inflames pyrophorus, though not sufficiently calcined, or containing some portion of moisture. But, in the first place, it is by no means certain that the atmosphere naturally contains nitric acid: and again, M. Proust has discovered, that the inflammation of pyrophorus by spirit of nitre is owing to the coal which it contains; for the nitric acid detonizes with all carbonaceous matters that are sufficiently dry, and not too closely united by the force of aggregation; as we shall explain more at large when we come to the article of coal. Mr Bewly's explanation of this phenomenon is, therefore, not more satisfactory than those of former chemists.

The only way by which we can hope to discover the cause of this phenomenon is, making ourselves intimately acquainted with the nature of Homberg's pyrophorus. It appears to consist of aluminous earth, a loose carbonaceous matter, supplied by the honey or sugar, &c. a little potash, and a small portion of sulphur, united partly with the aluminous earth and in part with the alkali. When pyrophorus is strongly heated in a pneumato-chemical machine, a large proportion of sulphurated or *hepatic* hydrogenous gas is
ob.

obtained from it. When it becomes incapable of furnishing this substance, it is no longer susceptible of inflammation in the air. Pyrophorus, immersed in vital air, burns rapidly, giving out a very bright red flame. When washed with warm water, it affords genuine aluminous *sulphure*, leaving on the surface of the filter or strainer carbonaceous matter with a little aluminous earth. The pyrophorus is then decomposed. When pyrophorus ceases to burn, it is found to have acquired an increase of weight by absorbing a portion of oxygen. If when in this state it be lixiviated, it affords aluminous sulphate; because the sulphur burnt by the action of the air forms sulphuric acid which combines with the aluminous earth. But the salt thus obtained is alum saturated with earth.

The *Journal de Physique* for November 1780, contains some observations on pyrophorus, in which we are told, 1. That this substance owes its combustibility to its containing a certain quantity of phosphorus formed by the acid of mucous matters. 2. That an ounce of pyrophorus gives, when distilled, from five to seven grains of phosphorus. 3. That pyrophorus may be at any time readily composed by triturating fifty-four grains of flowers of sulphur, thirty-six of very dry charcoal of willows, and three of common phosphorus, together in an iron mortar. The particulars of the analysis do not exactly correspond with the inductions deduced from it; for it does not appear that real phosphorus was obtained. But the memoir contains a number of important facts, which it may be advantageous to any chemists who shall hereafter attempt an analysis of pyrophorus to be acquainted with.

Alum is applied to many useful purposes. In medicine, it is used as an astringent: but it should be

very cautiously administered internally. It is oftener applied externally as a stiptic and a powerful desiccative. It is used in gargles, plasters, collyria, &c.

Few saline matters are of more use in the arts than alum. Chandlers mix it with their tallow, to render it more solid and consistent. Printers rub their balls with calcined alum, to make them take up the ink. Wood impregnated with a solution of alum will scarcely burn. And the use of alum has therefore been proposed to secure houses from taking fire. It produces the same effects on paper as on wood. But paper impregnated with alum soon becomes yellow, and suffers an alteration of nature.

Bleachers put a little alum into muddy water to purify it. M. Baumé thinks, that on this occasion the salt attracts to it part of the earth suspended in the fluid, and that the earth and the salt forming an insoluble compound, are precipitated together. Some people use alum to purify water which they are going to drink. It is used in preparing leather; and cloth and paper, on which colours are to be impressed, are first impregnated with alum.

A solution of alum retards the putrefaction of animal substances. This is an excellent, and a very cheap way of preserving natural productions which are sent as specimens from one country into another. Aluminous earth constitutes the base or body of pastils or crayons. And, lastly, this salt is, as Macquer says, the very soul of the art of dyeing. It renders colours deeper and more bright, and it confers solidity on the particles of colouring matters; without the help of alum no colour would be permanent or proof against water. This property of alum will be examined when

we come to speak of colouring vegetable matters. We will then see that alum renders them permanent by changing their nature, decomposing them, and making them insoluble in water.

Species II. *Aluminous Nitrate.*

M. Baumé says, that the nitric acid entirely dissolves aluminous earth. This solution is limpid, and much more astringent than a solution of alum. By spontaneous evaporation, it gives small pyramidal crystals, extremely stiptic, and liable to deliquiate.

The other properties of this salt have not yet been examined; only we know that it admits of decomposition by the intervention of the same substances which decompose alum. It has not yet been found in nature, but is always a product of art.

Species III. *Aluminous Muriate.*

THE muriatic acid dissolves aluminous earth better than the nitric acid. This solution, when the substances are mutually saturated, is gelatinous, nor can it be filtrated without being diluted in a great deal of water. Aluminous muriate has a salt stiptic taste; it first reddens syrup of violets, and afterwards converts it to a green. By spontaneous evaporation it gives very stiptic crystals, the form of which has not yet been examined: lime-water decomposes them. Aluminous muriate is liable to deliquiate. It has never yet been obtained but by the manipulations of art. Its other properties are unknown.

Species IV. *Aluminous Borate.*

THE combination of the boracic acid with aluminous earth, which we call *aluminous borate*, has not as yet been examined. We know that when a solution of borate of soda is poured into a solution of aluminous sulphate, it produces a light flaky precipitate. The sulphuric acid forsakes the aluminous earth, in order to combine with the soda. The earth again combines with the boracic acid, which is separated at the same time. And this new salt is by degrees dissolved again. The liquor thus precipitated by the fixed alkali gives by evaporation a viscous astringent mass, consisting of sulphate of soda and aluminous borate confounded together. This kind of borate may be decomposed in the same manner as alum; but its properties have not yet been examined with sufficient care.

Species V. *Aluminous Fluate.*

WE give this name to the combination of the fluoric acid with aluminous earth. This neutral salt is not known, and has never been examined. Scheele, Boullanger, and Bergman, have said nothing about it.

Species VI. *Aluminous Carbonate.*

THE combination of the carbonic acid with aluminous earth has been as yet but very little examined. It is certain, however, that the carbonic acid admits of combination with aluminous earth; For, 1. As Bergman
has

has remarked, when a solution of alum is precipitated by the alkaline carbonates, the filtrated liquor deposits, at the end of some time, a little earth which was held in solution by the carbonic acid, and is left in a separate state, as the acid gradually escapes. 2. This precipitation, when the matters are cold, takes place without any effervescence, and part of the carbonic acid separated by the alkali appears to enter into combination with the aluminous earth, while another part is dissolved in the liquor.

Besides, from the decomposition of many argillaceous earths by several modern chemists, it is at present known that they contain carbonic acid; for when dissolved in the sulphuric and the muriatic acids, they always effervesce either more or less.

C H A P.

CHAP. X.

Genus VI. *Barytic Neutral Salts, or Neutral Salts with a Base of Barytes.*

BARYTES in combination with the acids form a class of neutral salts, which differ from those which we have hitherto been examining, in form, taste, solubility, and in the laws of their decomposition. This earthy-alkaline substance has a greater affinity with the acids than any of the three alkalis, or of the other earths. These alkaline substances must be united with the carbonic acid, to enable them to decompose barytic salts. Those salts are six in number, namely, barytic sulphate, or ponderous spar, barytic nitrate, barytic muriate, barytic borate, barytic fluuate, and barytic carbonate. To these six we may add the combinations of barytes with the tungstenic, the arsenic, the molybdic, and the succinic acids: but as these are not much known, we will defer speaking of them till we come to the history of the four acids to which they owe their formation.

Species

Species I. *Barytic Sulphate, or Ponderous Spar.*

PONDEROUS spar, which being insipid and insoluble, has been hitherto considered by naturalists as a stone, is produced by the combination of the sulphuric acid with barytes; and should therefore be called *barytic sulphate*. This earthy salt has been by many naturalists confounded with *fluor spar*, or calcareous fluuate: both indeed have the same fracture, and effervesce in the same manner with acids. But the form, the obscurity, and the ponderosity of *ponderous spar*, plainly distinguish it from the other. Besides, it possesses one chemical quality, which alone might be sufficient to peculiarize its character. If a small portion of sulphuric acid be poured on powder of ponderous spar, the acid moistens the spar without disengaging from it any vapour, or causing it to exhale any smell; whereas calcareous fluuate, or *fluor spar*, when treated in the same manner, exhales by degrees a gas of a poignant smell, which, on coming into contact with air, composes a white smoke that is soon perceived to be fluoric acid. Other naturalists have confounded it with *jelenitous spar*: but this substance again is of a different form, and more soluble, and may be decomposed by the fixed alkalis in a pure or caustic state; whereas those salts effect no alteration on ponderous spar.

Barytic sulphate abounds in nature. It is almost always found along with metal ores. It appears either in crystals or in shapeless masses, but is always disposed in layers which vary in thickness and extent. It is pretty hard, yet does not give fire with steel. The following are its principal varieties.

Varieties.

Varieties.

1. Barytic sulphate, or *ponderous spar*, white, semi-transparent, and crystallized in prisms, of six sides, two of them very large, and the other four very little, terminating in dihædral summits. Those crystals are disposed in an oblique posture, on masses of the same nature with themselves. They resemble oblong square plates, the four sides of which have been cut obliquely. They are often covered with yellowish rhomboidal crystals. This, as well as the following species, is called *ponderous spar in tables*.
2. Barytic sulphate, or *milk-white ponderous spar*, in tables, but not having their sides cut asslant. It is not regularly crystallized, but is found in tolerably thick layers, arranged one over another. It is often incrustated with a red dust, of reddish silver ore, or *pyrites*.
3. Round, *semi-chatoyant*, barytic sulphate or *ponderous spar*: Bologna stone. It consists of a number of converging filaments united into laminæ, arranged one over another. This variety is better known than any of the others, on account of its being phosphoric. It plainly appears to have been agitated and worn by water.
4. Octohædral barytic sulphate or *ponderous spar*. It crystallizes like alum. The summits of the pyramids are often truncated, so as to form a decahædral figure. It exhibits a number of other varieties, according as its angles are prolonged or truncated.
5. Duodecahædral barytic sulphate or *ponderous spar*.

Varieties.

spar. It is of the form of certain garnets and some pyritous stones. It is seldomer to be met with than the preceding species.

6. Pyramidal barytic sulphate, or ponderous *spar*. Both this and the preceding variety appear in M. Daubenton's table.

I consider as a variety of *ponderous spar* that substance which is known by the name of *pearl spar*, and was formerly, as well as most of the preceding varieties, ranked among the *selenitous spars*. This *spar* consists of small rhomboidal scales, which are generally sparkling, and obliquely disposed one over another. It is opaque, brilliant, seemingly micaceous, and scattered over calcareous *spar*, quartz, or the first of the varieties above described. It is of a yellow or a dirty green colour, sometimes of a silver white. The Abbé Haüy thinks it to be a genuine calcareous *spar*.

Margraaf, who examined several varieties of barytic sulphate, such as Bologna stone and white opaque ponderous *spar*, imagined it to be a kind of *selenite* or calcareous sulphate, mixed with a little clay, which rendered it insoluble. But Gahn, Scheele, and Bergman, found it to be that peculiar earth to which we have given the name of *barytes*. M Monnet has likewise found, by examining the salts which it forms with acids, that its base is of a different nature from calcareous earth; but he imagines it to contain sulphur ready formed, and takes *ponderous spar* to be an earthy *liver of sulphur* in crystals.

Barytic sulphate, when exposed to a violent heat, such as that of a porcelain furnace, &c. melts into a glass more or less coloured. When exposed to a moderate

derate heat, it suffers no alteration. If carried into the dark, after being exposed for a little to a strong heat, it exhibits a very lively bluish light. Lemery tells us, that an Italian shoemaker, named Vincenzo Casciarolo, was the first who discovered the phosphoric quality of Bologna stone. Finding a stone of this kind at the foot of Mount Paterno, its brightness and gravity made him think it contained silver. He exposed it to fire, in order no doubt to extract from it if possible the precious metal, and observed, that when heated it gave light in the dark. Struck with the discovery, he repeated the experiment, and it constantly succeeded with him. A number of chemists and naturalists have successively directed their attention to this phenomenon, and have calcined Bologna stone in all the various ways they could contrive. The works of Poterie, Montalban, Mentzel, and Lemery, and the memoirs of Homberg, Dufay, and Margraaf, contain a variety of processes for performing this operation.

This property is at present known to be common to all varieties of barytic sulphate. They are made red hot in a crucible, beat in a glass mortar to a powder, formed into a paste with a little gum adraganth, and divided into cakes of the thickness of a knife blade. These cakes are dried, and exposed to a violent calcination among coals in a strong drawing furnace; nor are they taken out till the coals be entirely consumed and the furnace cold. The ashes are then blown off them with a pair of bellows; they are exposed to the light for a few minutes; and after this, when taken into the dark, they shine like a burning coal. Even in water they emit the same sparkling light, but gradually lose the property; which they regain, however, on being heated anew. But many substances display the

same

same phenomenon. Magnesia, chalk, calcareous sulphate, and calcareous fluatè, &c. become luminous, after being heated. Macquer has observed the existence of the same property in earth of alum, sulphate of potash, Briançon chalk, and black gun-stone calcined:—from which it appears that the presence of an acid is not absolutely necessary to the production of this phenomenon. Yet substances possessing an acid display it in a more eminent degree than others.

Margraaf could obtain no product by heating barytic sulphate. The substance, he found, suffered no alteration.

This salt is absolutely insoluble in water. The earthy and the salino-terreous matters act not upon it. The pure fixed alkalis do not decompose it; which is the most singular of all its properties. All the other earths and salino-terreous matters have a weaker affinity than the fixed alkalis with the sulphuric acid. But barytes has a stronger affinity with the acids than those salts. We have therefore observed, after Bergman, that this decomposes both sulphate of potash and sulphate of soda. It has the same influence on ammoniacal sulphate.

The mineral acids cannot act on barytic sulphate; for the sulphuric acid adheres with greater force than any of them to the earthy base of this salt. The neutral salts, excepting carbonate of potash and of soda, are equally incapable of acting upon barytic sulphate. These two saline substances, however, decompose it by double affinity. The barytes is separated from the sulphuric, because it is attracted by the carbonic acid; while the fixed alkali acts with equal force on the sulphuric acid. This decomposition is effected by exposing to a strong heat in a crucible a mixture consisting of

of two parts of carbonate of potash and one of barytic sulphate in powder. This matter, after being half vitrified by the heat, is lixiviated in distilled water. The liquor is filtered, and then affords by evaporation sulphate of potash. The matter which remains on the filter is barytic carbonate. After being well washed, it appears in the form of a very white fine pulverulent matter, but almost always contaminated with a portion of barytic sulphate, which has escaped decomposition.

As combustible bodies are capable of decomposing this salt, we may make use of them too when we wish to obtain its base separate. When a powder of this salt, mixed with a portion of coal equal to an eighth part of its weight, has been exposed to fire in a crucible, for two or three hours after the crucible became red hot,—if the matter be afterwards poured into distilled water, it will instantaneously communicate to the fluid a reddish yellow colour, with all the characteristics of a solution of earthy *sulphure*: for the coal robs the sulphuric acid of its oxigene, and the sulphur being of consequence left separate, combines with the barytes, and is thus reduced to *sulphure* or *hepar*. This solution of sulphure may be precipitated by an acid. The muriatic acid is preferred for this purpose, because it combines with the earth to form a soluble salt; whereas the sulphuric acid would form barytic sulphate, which is insoluble. The liquor is next filtered. The sulphur separated by the acid remains on the filter; and the water which has passed through it holds the barytic muriate in a state of solution. This solution again may be decomposed by a solution of carbonate of potash: the barytes, combining with the carbonic acid, is precipitated; and these two principles

ciples may be again separated by calcination, as we will show under a different article. This process, which I have often performed, gives but very little barytes; and we find on the filter through which the solution of the *hepar* has been caused to pass, after being precipitated by the muriatic acid,—nothing but a few particles of sulphur, unless it be exposed to a very violent heat. To help the decomposition of that earthy salt, Bergman and Scheele have directed about a fourth part of *fixed salt of tartar* to be added to the mixture of barytic sulphate and coal. The sulphur and the barytes are then easier separated; because the fixed alkali causes the matters to suffer a more complete fusion.

From these two processes for decomposing barytic sulphate, as well as from a view of its properties in general, it appears that the earth or salino-ferreous substance, which is the base of this salt, is of a peculiar nature, differing from aluminous earth, lime, and magnesia.

Barytic sulphate is of some use in the arts. Phosphoric cakes are prepared of it, and the barytes which it contains is extracted for the use of chemical laboratories.

Species II. *Barytic Nitrate.*

The nitric acid combines readily with barytes. The result of the combination is a neutral salt, in large hexagonal crystals, or small irregular crystals, according to M. d'Arcet. It is with great difficulty that we obtain it in crystals.

Barytic nitrate is decomposed by the action of fire, and gives out vital air.

It attracts the moisture of the atmosphere. A considerable quantity of water, however, is requisite to maintain it in solution.

Neither the pure alkalis, sand, aluminous earth, lime, nor magnesia, decomposes it.

Sulphuric acid poured into a solution of barytic nitrate, immediately produces a precipitate of barytic sulphate. The fluoric acid, too, robs this salt of its base.

Alkaline carbonate decomposes it by a double affinity.

This salt is but very little known.

Species III. *Barytic Muriate.*

THIS salt has been as little examined as the preceding. Bergman says that it is susceptible of crystallization, and does not dissolve easily. It may indeed be obtained in oblong square crystals, pretty much like those of ponderous spar in tables.

It is liable to no alteration or decomposition from sand, aluminous earth, magnesia, or caustic alkali.

The sulphuric and the fluoric acids decompose this salt by combining with its base.

Carbonate of potash or of soda precipitates the barytes in combination with the carbonic acid.

Bergman reckons barytic muriate to be one of the most sensible re-agents, and proposes to detect, by means of it, even the smallest portion of sulphuric acid that can possibly be contained in any mineral water. If a drop or two of a solution of this salt be poured into
about

about three pounds of water, containing twelve grains of sulphate of soda in crystals, it will immediately produce barytic sulphate in white striae, owing to the decomposition of both the salts, and the union of the sulphuric acid with the barytes. A portion of muriate of soda remains dissolved in the liquor. All sulphuric salts are equally affected by this re-agent; which always decomposes them to form barytic sulphate.

Species IV. *Barytic Borate.*

THIS combination of the boracic acid with barytes is entirely unknown. Bergman asserts that the acid of borax is among those which have the least affinity with the salino-terreous substances, and ranks it in his table below most of the vegetable and animal acids.

Species V. *Barytic Fluuate.*

THIS salt is as little known as the preceding; and, with many other saline matters that have not yet been examined, and on which we are therefore obliged to be very brief, affords matter for new experiments.

Bergman, in his dissertation on elective attractions, asserts, that when fluoric acid is poured into a solution of barytic nitrate or muriate, it occasions a precipitation; and that the precipitate thus produced effervesces with the sulphuric acid, which extricates the fluoric from it.

This instance proves the fluoric acid to have a greater affinity with barytes than either the nitric or the muriatic acid; and shows, that it forms, with this sa-

lino terreous substance a salt much less soluble than barytic nitrate or barytic muriate.

Species VI. *Barytic Carbonate.*

BARYTES combines with the carbonic acid to form a neutral salt possessed of some singular properties, and appearing to bear some relation to chalk.

We have already observed, that it is in consequence of the affinity subsisting between barytes and the carbonic acid, that barytic sulphate, and all barytic salts in general, are decomposed by alkaline carbonate. In these instances, barytic carbonate is always precipitated. This salt is likewise prepared by exposing to the air a solution of pure barytes. The surface of the liquor is gradually covered with a pellicle, which effervesces with acids, in consequence of the earth's being impregnated with carbonic acid from the atmosphere, and becoming thereby less soluble. This phenomenon resembles that which is exhibited by lime-water; and though barytes and lime differ widely in many of their other properties, yet here there is a striking analogy between them.

Barytic carbonate loses its acid when exposed to fire. If heated in a retort or matras fitted to a pneumatocchemical machine, it gives the acid in its natural gaseous form. Yet it is exceedingly difficult to separate the acid entirely, and a very intense heat is requisite for the purpose.

All the mineral acids decompose this salt, and disengage the carbonic acid. A lively effervescence is always produced on the occasion, which distinguishes this salt from pure or caustic barytes. Bergman rec-

kons

kons an hundred weight of this salt to contain seven parts of carbonic acid, sixty-five of barytes, and eight of water.

Water will scarce dissolve barytic carbonate; but when it is itself impregnated with carbonic acid, it dissolves a portion of this salt equal to an 1550th part of its own weight. From this it appears that barytic carbonate is still more difficult of solution than pure or caustic barytes: for, according to Bergman, water dissolves about a 900th part of pure barytes. This salt therefore appears, in this instance, to be subject nearly to the same laws with chalk or carbonate of lime, and like it is precipitated when the carbonic acid evaporates from the water which maintained it in solution. But in other respects there is a wide difference between them. The salts which barytes forms with other acids, show, as we have above observed, that it differs essentially from lime.

Barytic carbonate is of no use. It is found in nature.

C H A P. XI.

Recapitulation and Comparison of the Mineral Salts.

AFTER the above account of the present state of chemical knowledge respecting the properties of mineral salts, it may next be proper to take a brief comparative view of the principal characteristics, and the mutual affinities of those bodies.

I. Salts are distinguished by four general properties; taste, tendency to combination, solubility, and incombustibility. These properties exist in various degrees of energy; and the various degrees of their energy constitute the essential differences which diversify saline matters.

II. All salts may be arranged under four orders or four principal genera. 1. Salino-terreous substances, which possess the properties of both earths and salts. 2. Alkalis, the characteristics of which are, an urinous taste, and the property of converting many blue vegetable colours to green. 3. Acids, distinguished from other salts by their four taste, and by communicating

a red colour to blue vegetable matters. 4. Middle or neutral salts, which differ from the preceding as being of a weaker, but a mixed salt taste, bitter taste, and being less soluble, &c.

III. There are three salino-terreous substances; ponderous earth or barytes, magnesia, and lime. Their properties are pretty well known; but of their component principles we are ignorant. No chemist has hitherto separated any of these bodies into distinct principles, or formed them by combination. They are, therefore, actually simple in respect to the present state of the science. But they may, one day, perhaps be decomposed.

IV. We know of three alkalis; potash, called also *vegetable fixed alkali* and *alkali of tartar*; soda, likewise known under the name of *mineral alkali* or *marine alkali*; ammoniac or volatile alkali. The two first of these are dry, solid, caustic, fusible, liable to deliquesce, &c. When pure, it is impossible to distinguish between them; but they are readily distinguished by the manner in which they combine with acids. Hitherto we have obtained no certain experimental knowledge of their intimate composition: No body has yet separated them into principles, or formed them by combination.

The opinion which represents them as compounds of earth and water, is nothing more than an ingenious fancy, which must be given up because it is supported by no positive facts. Ammoniac differs from them in appearing under the form of an elastic fluid, strongly odorous, and susceptible of an amazing expansion, &c. It is at present known to consist of the bases of two gaseous substances,—inflammable gas or hydrogen, and atmospheric mephitic or azote. It is decomposed on

some occasions, and on others formed by combination. It appears that the two fixed alkalis likewise contain azote, and that this substance may be considered as the alkalifying or alkaligenous principle.

V. There are fix acids with which we are well acquainted; the carbonic, the muriatic, the fluoric, the nitric, the sulphuric, and the boracic acids. Each of these is distinguished by its peculiar properties. The carbonic, the muriatic, and the fluoric acids, are very easily made to assume the elastic or aeriform state. The case is not the same with the nitric and the sulphuric acids. The boracic acid is concrete and crystalline. The arsenic, the molybdic, and the tungstic acids, of which we are to speak in a kind of appendix to this part, are concrete, but pulverulent, and never crystalline.

VI. We are now beginning to understand the nature of the acids much better than formerly. The hypothesis which represented them as compounds of earth and water has been demonstrated to be quite improbable. The oxygenous principle, which is the base of vital air, is known to enter for one principle into their composition. And an acid is often formed by the union of oxygen with some combustible substance; with coal in the carbonic acid; with sulphur in the sulphuric; and with azote in the nitric acid. Another fact which concurs to prove that oxygen is a constituent principle in acids, is, the formation of a great many peculiar acids by the action of the nitric acid on combustible bodies.

VII. The acids unite, without suffering decomposition, with aluminous earth, barytes, magnesia, lime, the fixed alkalis, and ammoniac. From these combinations there result a great many neutral salts, which

are called *compound*, *middle*, or *neutral*. The substances which in these saline combinations neutralize the acids, are called *bases*.

VIII. The properties of the middle or neutral salts are different from those of their component principles; in most of them it is impossible to recognize any of the properties of either the acid or the base. The base, however, appears to communicate some general or common properties to neutral salts; for which reason we have classed them into genera by their bases.

IX. On this principle there are six genera of neutral salts, the order, the composition, and the nomenclature; of which it may here be proper to lay again before the reader.

Genus I. *Neutral Salts, with a base of Fixed Alkali.*

Species.

Ancient Names.

I. The sulphuric acid with potash.

SULPHATE OF POTASH.

{ *Vitriolated tartar, sal de duobus,*
arcanum duplicatum, vitriol of
potash.

II. The sulphuric acid with soda.

SULPHATE OF SODA.

Glauber salt, vitriol of soda.

III. The nitric acid with potash.

NITRATE OF POTASH.

Common nitre, saltpetre.

IV. The nitric acid with soda.

NITRATE OF SODA.

Cubic nitre, rhomboidal nitre.

V. The muriatic acid with potash.

MURIATE OF POTASH.

{ *Digestive salt, febrifuge salt of Syl-*
vius, regenerated marine salt.

VI. The

some occasions, and on others formed by combination. It appears that the two fixed alkalis likewise contain azote, and that this substance may be considered as the alkalifying or alkaligenous principle.

V. There are fix acids with which we are well acquainted; the carbonic, the muriatic, the fluoric, the nitric, the sulphuric, and the boracic acids. Each of these is distinguished by its peculiar properties. The carbonic, the muriatic, and the fluoric acids, are very easily made to assume the elastic or aeriform state. The case is not the same with the nitric and the sulphuric acids. The boracic acid is concrete and crystalline. The arsenic, the molybdic, and the tungstic acids, of which we are to speak in a kind of appendix to this part, are concrete, but pulverulent, and never crystalline.

VI. We are now beginning to understand the nature of the acids much better than formerly. The hypothesis which represented them as compounds of earth and water has been demonstrated to be quite improbable. The oxygenous principle, which is the base of vital air, is known to enter for one principle into their composition. And an acid is often formed by the union of oxigene with some combustible substance; with coal in the carbonic acid; with sulphur in the sulphuric; and with azote in the nitric acid. Another fact which concurs to prove that oxigene is a constituent principle in acids, is, the formation of a great many peculiar acids by the action of the nitric acid on combustible bodies.

VII. The acids unite, without suffering decomposition, with aluminous earth, barytes, magnesia, lime, the fixed alkalis, and ammoniac. From these combinations there result a great many neutral salts, which

are called *compound, middle, or neutral*. The substances which in these saline combinations neutralize the acids, are called *bases*.

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Genus I. *Neutral Salts, with a base of Fixed Alkali.*

Species.

Ancient Names.

I. The sulphuric acid with potash.

SULPHATE OF POTASH.

{ *Vitriolated tartar, sal de duobus, arcanum duplicatum, vitriol of potash.*

II. The sulphuric acid with soda.

SULPHATE OF SODA.

Glauber salt, vitriol of soda.

III. The nitric acid with potash.

NITRATE OF POTASH.

Common nitre, saltpetre.

IV. The nitric acid with soda.

NITRATE OF SODA.

Cubic nitre, rhomboidal nitre.

V. The muriatic acid with potash.

MURIATE OF POTASH.

{ *Digestive salt, febrifuge salt of Sylvius, regenerated marine salt.*

VI. The

Species.	Ancient Names.
VI. The muriatic acid with soda.	
MURIATE OF SODA.	{ Marine salt, sea salt, common salt, kitchen salt.
VII. The boracic acid with potash.	
BORATE OF POTASH.	Vegetable borax.
VIII. The boracic acid with soda.	
SUPERSATURATED BORATE OF SODA, or BORAX.	{ Common borax, tinckal.
IX. The fluoric acid with potash.	
FLUATE OF POTASH.	{ Spathose tartar. Spar of tartar.
X. The fluoric acid with soda.	
FLUATE OF SODA.	Sperry soda.
XI. The carbonic acid with potash.	
CARBONATE OF POTASH.	{ Cretaceous tartar, Chalk of potash.
XII. The carbonic acid with soda.	
CARBONATE OF SODA,	{ Cretaceous soda. Chalk of soda.

Genus II. *Ammoniacal Neutral Salts.*

Species.	Ancient Names.
I. The sulphuric acid with ammoniac.	
AMMONIACAL SULPHATE.	{ Glauber's secret ammoniacal salt, ammoniacal vitriol.
II. The nitric acid with ammoniac.	
AMMONIACAL NITRATE.	Ammoniacal nitre.

III The

Species.

Ancient Names.

III. The muriatic acid with ammoniac.

AMMONIACAL MURIATE.

Sal ammoniac.

IV. The fluoric acid with ammoniac.

AMMONIACAL FLUATE.

V. The boracic acid with ammoniac.

AMMONIACAL BORATE.

VI. The carbonic acid with ammoniac.

AMMONIACAL CARBONATE.

English sal volatile.
Concrete volatile alkali.
Ammoniacal chalk.

Genus III. *Calcareous Neutral Salts.*

Species.

Ancient Names.

I. The sulphuric acid with lime.

CALCAREOUS SULPHATE.

Plaster.
Gypsum.
Selenite.
Calcareous vitriol.

II. The nitric acid with lime.

CALCAREOUS NITRATE.

Calcareous nitre.

III. The muriatic acid with lime.

CALCAREOUS MURIATE.

Fixed sal ammoniac, oil of lime.
Calcareous marine salt.

IV. The fluoric acid with lime.

CALCAREOUS FLUATE.

Cubic spar, vitreous spar, fusible spar or fluor, sparry fluor, fluorated lime.

V. The

Species.

Ancient Names.

V. The boracic acid with lime.

CALCAREOUS BORATE.

VI. The carbonic acid with lime.

CARBONATE OF LIME.

{ Chalk, calcareous spar, calcareous earth.

Genus IV. *Magnesian Neutral Salts.*

Species.

Ancient Names.

I. The sulphuric acid with magnesia.

MAGNESIAN SULPHATE.

{ Salt of Epsom or Sedlitz, bitter cathartic salt, vitriol of magnesia.

II. The nitric acid with magnesia,
MAGNESIAN NITRATE.

III. The muriatic acid with magnesia.

MAGNESIAN MURIATE.

Marine salt, with a base of magnesia.

IV. The fluoric acid with magnesia.

MAGNESIAN FLUATE.

V. The boracic acid with magnesia.

MAGNESIAN BORATE.

VI. The carbonic acid with magnesia.

MAGNESIAN CARBONATE.

{ Effervescent magnesia.
Mild, aerated magnesia.
Magnesian chalk.Genus V. *Aluminous Neutral Salts.*

Species.

Ancient Names.

I. The sulphuric acid with aluminous earth.

ALUMINOUS SULPHATE.

Alum, vitriol of clay.

II. The

Species.

Ancient Names.

II. The nitric acid with aluminous earth.

ALUMINOUS NITRATE.

{ *Argillaceous nitre.*
 { *Nitrous alum.*

III. The muriatic acid with aluminous earth.

ALUMINOUS MURIATE.

{ *Argillaceous marine salt.*
 { *Marine alum.*

IV. The fluoric acid with aluminous earth.

ALUMINOUS FLUATE.

{ *Sparry clay.*
 { *Argillaceous fluor.*

V. The boracic acid with aluminous earth.

ALUMINOUS BORATE.

Argillaceous borax.

VI. The carbonic acid with aluminous earth.

ALUMINOUS CARBONATE.

{ *Effervescent clay.*
 { *Argillaceous chalk.*

Genus VI. *Neutral Salts, with a Base of Barytes, or Barytic Neutral Salts.*

Species.

Ancient Names.

I. The sulphuric acid with barytes.

BARYTIC SULPHATE.

{ *Ponderous spar.*
 { *Barotic vitriol.*

II. The nitric acid with barytes.

BARYTIC NITRATE.

{ *Ponderous nitre.*
 { *Barotic nitre.*

III. The muriatic acid with barytes.

BARYTIC MURIATE.

Ponderous marine salt.

IV. The

Species.

Ancient Names.

IV. The fluoric acid with barytes.

BARYTIC FLUATE.

V. The boracic acid with barytes.

BARYTIC BORATE.

{ *Aerated ponderous earth,*
 { *Cretaceous ponderous earth.*

VI. The carbonic acid with barytes.

BARYTIC CARBONATE.

Barotic chalk.

X. To these neutral salts we may join those which owe their nature to the arsenic, the molybdic, the tungstic, and the succinic acids; calling the first, *arseniates of potash, of soda, &c.*; the second, *molybdates of potash, of soda, ammoniacal, calcareous, &c.*; the third, *tungstates of potash, of soda, of lime, &c.*; the fourth, *succinates of potash, magnesia, aluminous earth, &c.* We will treat of these four genera of neutral salts in the history of metallic and bituminous substances.

XI. Each particular salt, whether simple or neutral, possesses certain peculiar characteristics, by which it may be distinguished from all the rest. These characteristic properties are taste, form, and alterability—by fire, air, earths, and the various saline substances. In order to learn to distinguish saline bodies readily, we must carefully study all their properties, compare them with one another, and mark their differences and contrarieties.

XII. Tho' most simple salts, and still more the neutral salts, be almost always products of art, yet nature sometimes affords them at the surface, or a very little beneath the surface of the earth. Barytes or pure magnesia have not been yet found in nature. Places lying near volcanoes afford lime: the fixed alkalis never ap-

pear in a caustic state, but always in combination with acids on the surface of the earth: the carbonic acid is diffused through the atmosphere, fills some subterraneous cavities, and exhales from certain waters: the muriatic acid appears to exist in a free state on the surface of the sea: the fluoric acid is never found but in combination with lime: the nitric acid is found beside or among putrefying matters: the sulphuric acid has been found in crystals by M. Baldostari in a grotto belonging to the baths of St. Philip in Italy, and by M. Dolomieu in a grotto on Mount Etna. M. Vandelli has observed, that in the neighbourhood of Sienna and Viterbo a solution of the sulphuric acid in water filtrates through the rocks. The sulphureous acid is continually disengaged in places exposed to the force of volcanic fires. M. Hoëfer has observed the boracic acid in solution on the water of several lakes in Tuscany.

XIII. Of the forty-two principal * species of neutral salts, of which we have given the history, only the following perfect neutral salts, that is, with a base of fixed alkali, are to be found on the surface of the earth, in the waters, or in the fluids of organized bodies. Sulphate of potash in vegetables; sulphate of soda in water and in some plants; nitre in vegetable juices, and in earths impregnated with putrid matters; muriate of potash in waters and in marine plants; muriate of soda, in earth, water, vegetables growing on the sea shore, and animal humours; carbonate of potash in vegetables;

* We speak not here of the modifications of those salts called *sulphites*, *nitrites*, *oxygenated muriates*, &c. nor of the twenty-eight species which owe their formation to the metallic and bituminous acids: the number of the neutral salts would by that means be much increased; and besides, it does not appear that these salts exist in nature.

tables; carbonate of soda in an efflorescence, on the earth, on stones, and in animal humours; there is some uncertainty in respect to borax. Nitrate of soda, fluuate of potash, fluuate of soda, and borate of potash, are always products of art.

XIV. We know of no ammoniacal salts existing ready formed in nature, but ammoniacal muriate, which is found in places contiguous to volcanoes, and ammoniacal carbonate which is formed in putrid animal matters: ammoniacal sulphate, ammoniacal nitrate, ammoniacal fluuate, and ammoniacal borate, are always formed by the chemist in his laboratory.

XV. Calcareous neutral salts abound over the surface of the globe. We know but of six species of this genus of neutral salts; and five of these have been found in nature. Calcareous sulphate or selenite exists in pretty extensive strata in hills: carbonate of lime, or calcareous matters, composes a considerable part of the exterior strata of the globe: calcareous nitrate is always found with common nitre in the beds in which it is produced: calcareous muriate, in like manner, always accompanies muriate of soda: calcareous fluuate is found in great plenty in mines.

XVI. Magnesian salts are much less copious in nature; none of them but magnesian sulphate and magnesian muriate, which are found dissolved in various waters, can be said to exist in nature: magnesian nitrate indeed is sometimes met with, but always in very trifling quantities. Nature has not yet exhibited to our observation either magnesian borate, magnesian fluuate, or magnesian carbonate. The last of these, however, appears to exist in some stones.

XVII. Barytic sulphate is the only one of the six barytic neutral salts that has been found in any abundance

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dance in the mineral kingdom. It is found in the cliffs of hills, and always in the neighbourhood of mines. Neither barytic nitrate, muriate, borate, nor fluuate, has as yet been known to exist in nature; but pure barytic carbonate was, a few months ago, discovered in England, finely crystallized, and in large masses.

XVIII. Aluminous sulphate is almost the only aluminous salt found in nature. It is met with in places adjacent to volcanoes, and among earths that have been exposed to the action of volcanic fires. It appears also in an efflorescence, on decomposed lava, &c. Pyrites in an efflorescent state likewise contain a portion of it. As to aluminous nitrate, muriate, borate, or fluuate, these are never found among the products of nature. Aluminous earth is often combined with the carbonic acid, and there is scarce any earth of the kind from which more or less of the carbonic acid may not be obtained by stronger acids.

C H A P: XII.

An Examination of some general Properties of Salts, particularly Crystallization, Fusibility, tendency to Effloresce or Deliquiate, Solubility, &c.

IN our history of simple and neutral salts, we have considered the properties of each salt separately: but it may likewise be proper to compare them; for from the comparison we may be able to deduce some general principles concerning them. Here then, let us consider in this point of view the crystallization, fusibility, efflorescence, deliquiescence, and solubility of salts.

Crystallization, considered as a general property of bodies, is a property by which they tend to assume a regular form, when placed in circumstances favourable to that particular disposition of their particles. Almost all minerals possess this property; but it is most eminent in saline substances. The circumstances which are favourable to the crystallization of salts, and without which it indeed cannot take place, may be all reduced to the two following: 1. Their particles must be divided and separated by a fluid, in order that the correspond-

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ing faces of those particles may meet and unite. 2. In order that this union may take place, the fluid which separates the integrant parts of the salt must be gradually carried off, so that it may no longer divide them. From this it may be understood, that crystallization takes place by virtue of the mutual affinity subsisting between the particles of crystallizable bodies, by which they tend to unite into one aggregate mass. These considerations lead us to think, that the integrant parts of salts have peculiar forms; and that the form of the integrant parts of the salt gives to the crystal its particular figure. The same considerations lead us farther to conclude, that the integrant particles of salts are small irregular sided polyhædrons, some of their faces being larger, others smaller, and that the largest of their faces most naturally meet and unite. This being allowed, it will be readily understood, that when the fluid which separates these particles is carried off, their corresponding faces will reunite; and if the fluid go off slowly, so as to give the saline matters time for a regular arrangement, and to allow them to bring their corresponding faces into contact, the crystallization will then be regular. But again, if the fluid be too quickly carried off, the saline particles must unite hastily, not by their corresponding faces, but by those which are most contiguous to each other, and the crystallization will then be irregular, and the form of the crystals not easy to determine. Nay, if the solution be very suddenly evaporated, the salt will appear in a concrete mass, with nothing of a crystalline form.

These are the principles on which we proceed when we attempt to make saline matters assume the crystalline form. All salts are susceptible of crystallization; but they do not all crystallize with equal readiness.

Some salts crystallize so readily, that we can make them assume the crystalline form at pleasure. Others again require more care and many precautions. And, lastly, there are several which we have not yet been able to obtain in crystals. In order to succeed in attempts to crystallize salts, it is requisite for us to be well acquainted with the circumstances most favourable to the crystallization of each. In such operations it is a necessary condition that the saline substances be first dissolved in water : but some salts are so difficult of solution that it is almost impossible to make their integrant particles unite regularly. Such are calcareous sulphate, calcareous carbonate, calcareous fluuate, and barytic sulphate. In nature, these neutral salts are daily met with in very regular crystals ; but art cannot imitate them but by a very tedious process ; nay, a number of eminent chemists deny the possibility of any such process. I take my account of it from M. Achard, who asserts, that by this process he obtained calcareous carbonate in crystals. This ingenious process consists in making water that has long stood over those salts which dissolve with so much difficulty, to run along a very narrow canal, and there evaporate very slowly. Again, there are other saline matters so soluble, and so much disposed to remain in union with water, that it is exceedingly difficult to separate them from it, and make them crystallize regularly. This is the character of all deliquiating salts, such as calcareous and magnesian nitrate and muriate.

Each particular salt, no doubt, must crystallize in a way peculiar to itself ; or, what is the same thing, the most minute particles of every saline substance must have a determinate form, by which they are distinguished from the integrant particles of every other saline

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line matter. This is doubtless the cause of that amazing variety of forms which crystalline bodies exhibit. The simple salts from the saline-terreous substances to the strongest acids, have scarce ever a distinct, determinate form: and there are but a few circumstances which can cause them to crystallize without totally destroying their saline properties; which actually happens to the oxygenated muriatic and the concrete sulphuric acids. The caustic alkalis, however, crystallize in plates, according to M. Berthollet, and the acid of borax is well known to exhibit the same figure. But excepting these two, none of the simple salts can be made to assume any regular form, either because their nature does not admit of it, or because the means which they employ are inadequate to the purpose. But all the neutral or middle salts naturally affect a regular form, and we can even cause most of them to assume or resign it at pleasure. When we consider this property by which neutral salts are so eminently distinguished from the simple, we are at a loss to determine whether it be owing to the acids or to the alkaline bases by which they are neutralized: but it cannot be exclusively ascribed to either the one or the other; for the same acid in combination with various bases often forms crystals of a great variety of figures; while again the same base in combination with various acids often exhibits a like diversity of forms. The crystallization of neutral salts is therefore to be ascribed to a total change of the properties of both the acid and the base.

There are three ways of making salts crystallize commonly practised in the laboratory. 1. The first is evaporation. This process consists in heating a saline solution till the water by which its particles are kept separate be reduced to vapour. The slower the evaporation,

poration, so much the more regular will the crystallization of the salts be. The process for crystallizing sulphate of potash, muriate of potash, muriate of soda, calcareous sulphate, and magnesian carbonate, is conducted on this principle. When a solution of any of these salts is evaporated by a boiling heat, the form in which the salt is obtained is far from being regular: but if placed on a sand bath, of the heat of nearly 45 degrees, the same solution constantly gives either sooner or later very beautiful regular crystals: And there is scarce any salt which may not be made to assume a regular form by this process judiciously conducted.

2. Cooling is successfully applied to crystallize such salts as are more soluble in warm than in cold water. It is easy to see, that a salt of this nature will crystallize as soon as the water in which it is dissolved becomes incapable of maintaining it fully in solution, in consequence of its temperature being diminished. That portion of the salt which owed its solution to the temperature of the fluid, is gradually separated as the liquor cools; and when the water becomes quite cold, no more of the salt remains dissolved but what is soluble in cold water. In this process, as in the former, when the solution is cooled most slowly, and the saline particles are suffered to unite their corresponding faces, the crystals are then most regular: And therefore solutions of salts should be for some time exposed to a certain degree of heat; which should be afterwards diminished gradually till it be reduced to the lowest degree requisite. It is to be observed, that all salts susceptible of crystallization by this process are in general much more soluble than those which are crystallized by the first process; as they are at first dissolved in boiling water, if the solution be suddenly cooled, the salt falls to the bottom in a shapeless mass; but if put

on a sand-bath, and slowly cooled, the crystallization is always regular. By this means sulphate of soda, nitre, carbonate of potash, carbonate of soda, ammoniacal muriate, &c. are obtained in fine crystals.

3. The third method of crystallizing salts is spontaneous evaporation. This is obtained by exposing a very pure solution of the salt which we wish to crystallize to the temperature of the atmosphere in a glass or stone vessel covered with gauze; which prevents any dust from falling into the liquor without retarding the evaporation. The vessel with the solution is to be set aside in an apartment not otherwise occupied, and there suffered to remain till crystals appear; four or five months, or perhaps a longer space, will sometimes elapse before that happen. The largest and most regular crystals are usually obtained by this process. Did time allow, it might be applied to all salts; for by means of it they are obtained in the highest purity. It is absolutely necessary for the crystallization of nitrate of soda, muriate of soda, borax, aluminous sulphate, magnesian sulphate, ammoniacal sulphate, ammoniacal nitrate, &c.

On some occasions two or more of these processes are employed together; as for instance, in the crystallization of salts which have a strong tendency to deliquesce, such as calcareous nitrate, calcareous muriate, magnesian nitrate, and magnesian muriate. Solutions are first powerfully evaporated, and then exposed to an extreme cold. But this method never gives regular crystals; and sometimes we obtain by it nothing but shapeless concrete masses. The reason why we are able to crystallize so few of the neutral salts, is our not knowing exactly in what state of concentration the solutions of various salts must be, in order that they may afford crystals. Though this knowledge

might easily be obtained, as nothing but time and patience are requisite for the purpose, yet chemists have not made it sufficiently the object of their attention. The specific gravities of saline solutions must be observed, in order that we may come to know the degree of concentration requisite for the crystallization of each. In some operations on salts in the great way, an areometer, or instrument for measuring the specific gravities of liquids, has been happily employed to determine the point at which the solution might be expected to crystallize.

Besides these methods of effecting the crystallization of salts, there are several circumstances favourable to that operation, the influence of which it will be proper to estimate. Gentle agitation sometimes contributes to effect a crystallization, which might otherwise not succeed. When vessels containing saline solutions are shaken or removed from one place to another, we sometimes see crystals instantly formed, though the saline matter was immediately before entirely in solution. The contact of the air is indispensably necessary to the formation of crystals. It often happens that a saline solution, though evaporated to the proper point, gives no crystals, on account of its being confined in a close flask; whereas if it were exposed to the air in an open vessel, it would crystallize with great rapidity. Rouelle the elder made this observation in a very accurate manner. The form of the vessels, too, and extraneous matters happening to be intermixed with the solution, have great influence on the crystallization of a salt. The first of these circumstances modifies the figure of the crystals, and diversifies them in an amazing manner. Thus, threads or small sticks are put into vessels containing saline solutions, to make them crystallize with

with greater regularity. The crystals are deposited on the threads, their bases are then very narrow, and they therefore assume a more regular form than when they fall upon the sides of earthen pots, or any of the other vessels commonly made use of in this process; which being oblique, irregular, and unequal, mutilate and destroy the regularity of crystals. Extraneous bodies immersed into solutions of salts are often serviceable; they cause the crystallization to take place sooner than it would otherwise have done. A bit of wood or a stone thrown into a salt spring, becomes a base on which the water deposits crystals of muriate of soda. Some chemists, in consequence of observing this phenomenon, have been induced to propose the immersion of saline crystals into saline solutions, which do not crystallize readily. Several have asserted this circumstance to be highly favourable to the crystallization of such salts as cannot without great difficulty be obtained under a regular form. These are the chief circumstances which influence crystallization. Future observation, no doubt, may make chemists acquainted with many more.

A salt cannot be separated from the water by which it was dissolved, so as to assume a regular form, unless it retain some part of the fluid. The reader may convince himself of this fact by taking a portion of some salt reduced to a powder by heat, such as aluminous sulphate or borate of soda calcined, or dried sulphate of soda, dissolving it in water, and causing it to crystallize: and it will be found to have gained an augmentation, sometimes even of an half more, in consequence of being crystallized; that is, an ounce of salt will increase to two ounces by crystallization. Chemists have inferred from this fact, that a salt when formed into regular

gular crystals, contains more water than when deprived of its crystalline form by the action of fire or air. This water, which though not one of its principles as a saline substance, is yet essentially necessary to its conformation into crystals they call *the water of crystallization*; because it is in fact an element of saline crystals. When deprived of this water, crystals lose their transparency and regularity of form. Salts contain some a greater some a less quantity of this water of crystallization. Some salts, such as sulphate of soda, carbonate of soda, and aluminous sulphate, contain a quantity of water equal to half their weight; others, such as nitre, muriate of soda, &c. possess but a small portion of water. The various proportions in which the water of crystallization subsists in the various salts has not yet been accurately determined. Salts may lose this water without suffering any alteration of their intimate nature; and the water itself is perfectly pure like distilled water.

As from what we have said concerning the crystallization of salts, it appears that saline substances are not all crystallized by the same process, but obey different laws in their formation into crystals; it is plain that we may take advantage of this circumstance, when we attempt to separate different salts from one another. Thus a salt which crystallizes by cooling may be obtained entirely separate from another which crystallizes only by continued evaporation; in this manner are the muriate of soda and the sulphate of soda, contained in the spring-waters of Lorraine, separated from each other. It often happens, however, that two salts when dissolved in the same water, are so blended together, that repeated solutions and crystallizations are necessary to effect an entire separation between them. This

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observation holds still more strongly in regard to those salts which are subject to the same laws of crystallization. These are much more difficult to separate from each other, especially if there be a number of them together. For instance, if the same water should happen to contain four different salts, all equally disposed to crystallize by either evaporation or cooling, it would not be possible to separate them by one or two successive processes of crystallization: but the operation would require to be many times repeated, in order that the nice variations which diversify the characters of those salts might be brought to display themselves: For it is to be remarked, that though two or more salts appear subject to the same laws of crystallization; yet when minutely observed, the crystallization of the one will be always found distinguished from that of the other by some slight differences. Were this not the case, they would always crystallize together, nor would it be at any time possible to obtain them separate; but this scarce ever happens, even in regard to those salts which crystallize in the most uniform manner. There are, however, some exceptions from this rule: some salts have a peculiar tendency to mutual adhesion, or an uncommon affinity with each other. Of this kind are all neutral salts which owe their formation to the same acid, and crystallize by the same process; such as the magnesian and ammoniacal sulphates. But these singular phenomena of neutral salts have not been as yet observed with enough of attention; and there is here still farther scope for the researches of the chemist.

Lastly, To conclude this compendious history of the crystallization of salts, let us take notice that there is another mode of obtaining them in crystals. Saline solu-

solutions may be precipitated by some substance that has a greater affinity than they with the water. Spirit of wine produces this effect on most of the neutral salts; on all of them indeed but such as are soluble in that menstruum. The same phænomenon takes place when salts, differing considerably from each other in point of solubility, happen to be mixed together, even when several different saline solutions are mixed, though the salts differ not greatly as to solubility. Thus sulphate of magnesia dissolved in water precipitates a solution of ammoniacal sulphate. But what passes on that occasion has not yet been observed with sufficient attention to enable me to give a particular account of this singular phænomenon.

Fusion by heat was treated of when we gave the particular history of each saline substance by itself; but we may here compare the different kinds of fusion of which salts are susceptible. Salts are liable to two kinds of fusion; the one, which is peculiar to saline matters, is owing to water, and is called *aqueous fusion*: the other, which arises from a different cause, is known by the name of *igneous fusion*. Aqueous fusion depends entirely on the water of crystallization; which as it exists in many salts in a large proportion, amounting often to half the weight of the crystal; is capable of dissolving such salts when heated to the temperature of 60 degrees. The crystalline form then disappears, the salt is dissolved, and the fusion which takes place is in fact a real solution. This observation is so just, that when a salt of this nature, such as sulphate of soda, borate of soda, or aluminous sulphate, is kept for some time in this state of fusion, the water which with the help of heat dissolved it, is gradually evaporated, and the salt is left dry, and no longer appears in a state of fusion,

fusion. This apparent or aqueous fusion has no relation to true igneous fusion; for all salts that have been dried after being once liquefied by their water of crystallization are susceptible of the latter. Thus muriate of soda, and borate of soda, are melted by a strong heat, after suffering aqueous fusion and being dried up by a moderate heat. All salts have not an equal tendency to true igneous fusion: There are some, such as nitrate and muriate of soda, which melt as soon as they begin to become red-hot: others again, such as sulphate of potash and sulphate of soda, require a much more intense heat to melt them. Lastly, Such is the fusibility of some salts, that they are capable of communicating this property to other bodies scarce fusible by themselves. Thus the fixed alkalis communicate their fusibility to quartz, sand, and all other siliceous earths, which are otherwise absolutely infusible. This property has acquired to these salts the title of *fluxes*, because they are employed to promote the fusion and vitrification of earthy and metallic substances. We have already remarked in another place, that the last degree of fusibility is volatilization. And we would here observe, that all saline matters are more or less volatile; not one of them but may be volatilized by an extreme heat. Thus sulphate of potash and muriate of soda, when heated to the highest temperature of which they are capable, are sublimated into vapour.

Crystallized salts do not all suffer the same alteration from the action of air. Some of them suffer no discernible alteration when exposed to it, but many lose sooner or later their transparency and form; and of these some melt down gradually, acquiring at the same time additional weight, while others, as they become pulverulent, suffer a diminution of weight. The first

of these alterations is called *deliquescence*, the other *efflorescence*.

That phænomenon which is known by the name of *deliquescence*, is so called because the saline matter which exhibits it then becomes liquid; and a salt is said to fall into a *deliquium*, when it melts in this manner on coming into contact with air. The word *desfaillance* was formerly used by *French* chemists as synonymous with *deliquescence*, but it is now become antiquated, and no longer appears in the writings of chemists. The occasion of this alteration is, that the salts attract the moisture of the atmosphere; which, in my opinion, is to be considered as a real elective attraction between the water and the salt, which acts with such superior force as to separate the water from the air of the atmosphere. There are also differences among salts, in regard to their tendency to deliquiate, both in respect to the rapidity with which this change takes place, and the point of saturation at which the phænomenon of deliquescence ceases. The fixed alkalis, ammoniac gas, the muriatic acid gas, and the concentrated sulphuric acid, abstract the water from the atmosphere, dry up the air, if we may be allowed to use the expression, with a very considerable force, and absorb a quantity of the fluid more than equal to their original weight. Dry potash particularly displays this phænomenon in a very eminent manner; so likewise does the sulphuric acid when concreted by cold. These two salts first become soft, and afterwards assume a thick liquid consistency, resembling that of some oils; which has caused the first to receive the name of *oil of tartar*, and the second to be called *oil of vitriol*. But these names are improper, and more likely to mislead than to enlighten a person entering upon the study of chemistry.

chemistry. There are other salts which have a strong tendency to deliquiate, but do not attract moisture so copiously or with so much avidity as those above-mentioned. Such are calcareous nitrate and calcareous muriate, magnesian nitrate and magnesian muriate. Lastly, There are some salts which, when exposed to the atmosphere, only become a little wet, without wasting entirely down, such as nitrate of soda, muriate of potash, ammoniacal sulphate, &c.

The phænomenon of efflorescence has been so named, because the salts susceptible of it appear covered over with small white threads, resembling those sublimated matters which are known in chemistry by the name of *flowers*. This property is the direct contrary of deliquescence. In the instance of deliquescence, the saline crystals decompose moist air; because the elective attraction subsisting between the salt and the water is stronger than that between the water and the air. In efflorescence, again, the atmosphere decomposes the saline crystals, as having a greater affinity with water than the salts. In efflorescence, therefore, the water of crystallization is abstracted from the salts; and this is the reason why salts, when they effloresce, lose their form, their transparency, and a part of their bulk. It is here of importance to observe, that all efflorescent saline crystals suffer from air an alteration similar to that which they suffer from heat. It is a kind of cold calcination which slowly decomposes crystallized salts, by separating from them the water to which they owe their crystalline form, and all their other properties as saline crystals. When a salt therefore effloresces entirely, it suffers exactly the same loss of weight as when it is dried by the action of fire. We may farther remark, that those salts whose crystals effloresce, belong to the class

class which is the most soluble, and crystallizes by cooling.

Efflorescence, like deliquescence, is not exactly the same in all the neutral salts susceptible of it. Some, such as sulphate and carbonate of soda, effloresce readily and entirely, so that after exhibiting this phenomenon, they are found to be wholly reduced to a fine white dust. As they appear to have lost, in consequence of this decomposition, half their weight, it may be inferred, that their efflorescing so completely is owing to their containing so much water of crystallization. And it is a fact, that salts which are but little susceptible of efflorescence, such as aluminous and magnesian borate and sulphate, contain less water in their crystals. If efflorescence depend on air's having a greater affinity with water than salts have, it must follow, that when the atmosphere is very dry, this phenomenon will take place more readily and in a more remarkable manner, while air loaded with moisture will not act in the same manner on efflorescent salts, but will leave them uninjured. To confirm this assertion; if a small portion of water be sprinkled on saline crystals susceptible of efflorescence, the surrounding atmosphere being saturated by the absorption of this water, does not affect that which enters into the conformation of the crystals, but leaves them unaltered. But if the crystals be not again wetted after the atmosphere has once absorbed the water which defended them against its influence, the air then makes an impression on the saline substance and destroys its crystallization. In apothecaries shops, this phenomenon is daily observed; for they find it necessary to keep sulphate of soda, or *Glauber salt*, constantly wet with a little water, in order to preserve it in crystals.

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The solution of salts in water is one of those phenomena which are most worthy of the chemist's attention. Some persons observing that it takes place without any sensible motion, and without the effervescence which always accompanies the solution of metals in acids, have proposed to call the one *solution*, and the other, which is attended with effervescence, *dissolution*. But as these two expressions have precisely the same meaning, and the reciprocal action of acids and metals is a phenomenon very different from the solution of salts, we do not think that this distinction can be attended with any advantage. The solution of salts has been considered by some philosophical chemists as being simply a mechanical division of the saline particles: but the two bodies penetrate each other in a very intimate manner; their temperature too is instantly changed, and a real combination appears to take place between the salts and the water, which cannot be explained by referring it to the mere separation of the saline particles. This appears, not only from the change of temperature which takes place on these occasions, but likewise from the possibility of separating one salt from water by the application of another which has a greater affinity with the fluid: thus potash precipitates sulphate of potash, and calcareous carbonate from water in which either of these salts are dissolved. All the precipitations of salts are far from being well known; and therefore a series of experiments investigating them would be of great use to chemistry. The reader might observe in the particular history of every saline substance, that they possess different degrees of solubility; some having such a tendency to combine with water, that they remain always fluid, as for instance, the sulphuric and the nitric acids; while others, such as barytic sulphate, are almost

perfectly insoluble. Several chemists have already attempted to exhibit in tables the various degrees of solubility of the different salts. But such tables must always be incomplete till such time as the solubilities of the different salts be very accurately determined by a numerous train of experiments. We may here again take notice, that all simple salts, whether alkaline or acid, constantly produce heat when dissolved in water; whereas cold is constantly excited during the solution of neutral salts. The changes of temperature which the different simple and neutral salts suffer on being dissolved in water are not yet fully known; but chemists are now beginning to pay more attention to that object than they formerly did. Some useful discoveries will surely be the result of such a train of researches; it has already led to the knowledge of some truths, which were not even guessed at before. For instance, when we observe that the neutral salts which produce most cold when dissolved, such as sulphate of soda, ammoniacal nitrate, and ammoniacal muriate, are much more soluble in warm than in cold water; is it not reasonable to infer, that this phenomenon is owing to their finding in warm water a greater quantity of heat than it is requisite for them to absorb, in order that they may be liquefied? And in fact they are easily deprived of this excess of heat by the action of air; so that part of the salt is precipitated in crystals as the liquor cools.

C H A P.

C H A P. XIII.

Of the Elective Attractions which take place between different Saline Matters.

THE numerous discoveries made by chemists concerning the nature of saline matters since the middle of the present century, have established it as a certain fact, that there subsist between these matters different degrees of affinity or elective attraction. Geoffroy was the first who compared them together; but late researches have shown, that his table was very erroneous. Bergman has corrected his errors, and has made us acquainted with many more of the elective attractions subsisting among salts: Yet, on consulting the articles of the celebrated Swedish chemist's table, which relate to the elective attractions of saline substances, we find several which are not founded on a sufficient number of experiments, and the uncertainty of which he himself acknowledges. Instead of extending the theory of elective attractions to so great a number of salts as Bergman has, we must confine it in

the present state of chemistry to the examination of the affinities which take place between those saline matters whose nature and properties are best known.

Of the six species of acids which we have examined, the sulphuric acid appears to be the strongest, or to have the most remarkable elective attractions for the different bases; that is to say, it separates most of the alkaline or saline-terreous bases from the other acids; it decomposes nitrates, muriates, fluates, borates, and carbonates, by extricating their acids.

The nitric acid generally holds the second rank: it yields the alkaline bases to the sulphuric acid; but attracts them from the four following acids.

In order to make the reader better acquainted with the different affinities which take place between the mineral acids and the saline bases of the same kingdom, we shall lay them down in the order in which Bergman arranges them in his Table of Affinities. Let us consider, 1. Each acid as related to the different saline bases with which it may be combined: 2. Each of the alkaline matters in relation to the acids which saturate them, and to the degree of force with which they combine with these salts.

I. The elective attractions of the sulphuric acid for the different bases, are arranged by Bergman in the following order, beginning with that base with which it has the strongest adhesion *.

The

* We have already given the order of the affinities of the acids with the bases in the history of each of those substances; but we think proper to exhibit them here in columns, as is done in tables of affinities, in order that they may appear under one point of view, and be compared together. A.

The SULPHURIC ACID.

Barytes.
 Potash.
 Soda.
 Lime.
 Ammoniac.
 Magnesia.
 Aluminous earth.

As the nitric and the muriatic acids attract the alkaline bases in the same order, we may give them immediately after the sulphuric acid.

The NITRIC ACID.

Barytes.
 Potash.
 Soda.
 Lime.
 Ammoniac.
 Magnesia.
 Aluminous earth.

The MURIATIC ACID.

Barytes.
 Potash.
 Soda.
 Lime.
 Ammoniac.
 Magnesia.
 Aluminous earth.

F 3

Barytes

Barytes has therefore a greater affinity than any of the other bases with the sulphuric, the nitric, and the muriatic acids, and decomposes all neutral salts that are formed by the union of these acids with the alkaline matters. Bergman places magnesia before ammoniac, because, he tells us, that salino-terreous substance decomposes ammoniacal salts. We may remark, that ammoniac decomposes magnesian salts more completely. Magnesia indeed is never entirely precipitated by this alkali. Mixed or triple salts are found to remain in the liquor, which are formed by the union of the magnesian with the ammoniacal salts. We apprehend, notwithstanding our respect for the authority of Bergman, that there is a greater affinity between ammoniac and the acids than between the acids and magnesia: for though magnesia disengages a little ammoniac from ammoniacal salts in the humid way, yet it does not decompose these salts by distillation. We have therefore placed ammoniac before magnesia; and we think Bergman's table needs this correction.

II. The elective attractions of the fluoric acid for the alkaline bases are very different from those of the three foregoing acids. The alkalis yield this acid to lime and the two other salino-terreous substances. A solution of barytic fluuate in hot water is precipitated by lime-water; and the precipitation is immediately followed by the formation of calcareous fluuate. The case is the same with the other fluoric neutral salts: lime deprives them of the acid,—as Bergman shows in his eighth table, which is thus arranged.

THE FLUORIC ACID.

Lime.
 Barytes.
 Magnesia.
 Potash.
 Soda.
 Ammoniac.
 Aluminous earth.

The same phænomena take place in the dry way ; for calcareous fluat is decomposed by carbonate of potash and of soda, but not by the pure and caustic fixed alkalis.

III. Bergman exhibits in his tenth table the affinities of the boracic acid in the same order with those of the fluoric ; because, when borax is heated with quicklime in water, the quicklime seizing the acid forms with it calcareous borate which is scarce soluble, and leaves the soda pure. As to the other bases, he gives the order of their affinities with this acid only by analogy ; and he acknowledges his disposition of them to be no more than a probable conjecture. *Quod idem accidat, says he, cum alkali vegetabili, acido boracis saturato, hætenus tantum probabilis est conjectura, æque ac terræ ponderosæ et magnesiæ positura.*

THE ACID OF BORAX.

Lime.
 Barytes.
 Magnesia.

F 4

Potash.

Potash.
Soda.
Ammoniac.
Aluminous earth.

IV. The elective attractions of the carbonic acid are somewhat different from those which have been laid down as belonging to the other acids. This acid adheres more strongly to barytes, and next after barytes to lime, than to any other substance. Ammoniac separates it from magnesia, as Bergman has shown by very accurate experiments. Here therefore we cannot make the observation which we have made with respect to the other acids; and we shall give part of the twenty-fifth column of that celebrated chemist's table of affinities, which exhibits the attractions of the carbonic acid for the several saline bases.

THE CARBONIC ACID.

Barytes,
Lime.
Potash,
Soda.
Magnesia,
Ammoniac,
Aluminous earth.

V. The seven earthy or alkaline bases whose combinations with the mineral acids we have examined, differ from one another in their elective attractions for the same acids. Five of them, namely the two fixed alkalis, ammoniac, lime, and aluminous earth, agree in the order of their affinities. All the five adhere to

the acids in the following order; the sulphuric acid, the nitric acid, the muriatic acid, the fluoric acid, the boracic acid, and the carbonic acid. But barytes and magnesia differ from the five first bases in their affinities with the mineral acids, and agree with each other.

Bergman disposes the elective attractions of barytes and magnesia, in respect to the mineral acids, in the following order.

BARYTES AND MAGNESIA.

The sulphuric acid.

The fluoric acid.

The nitric acid.

The muriatic acid.

The boracic acid.

The carbonic acid.

The only difference between these affinities and those of the five foregoing bases, is, that the fluoric acid here stands before the nitric and the muriatic acids; which shows that barytic and magnesian nitrates and muriates are decomposed by the fluoric acid;—whereas barytic and magnesian fluates are not liable to be deprived of their bases by the nitric and the muriatic acids.

VI. The elective attractions of which we have given an account, show the order of the simple decompositions which are effected when three saline matters are mixed together. But it is not enough to know these affinities or simple elective attractions; we must also

also attend to those which take place among four saline substances.

It is to be remembered, that by double affinity, we understand a double affinity in virtue of which a compound of two bodies which could not have been destroyed by either a third or a fourth body separately, is yet decomposed with the greatest facility when these two last bodies are combined together. This double elective attraction often takes place among neutral salts. Thus, calcareous sulphate, nitrate, or muriate, cannot be decomposed by either ammoniac or the carbonic acid taken separately: because the first of these bodies has less affinity than lime with the sulphuric, the nitric, and the muriatic acids; and the second again has less affinity with lime than even these acids: But when these calcareous salts are brought into contact with a compound of ammoniac and the carbonic acid, that compound destroys the adhesion of their principles. In that chapter in which I treated of affinities in general, I have shown how this phenomenon may be explained, by numbering the degrees of the attractive force exerted on the occasion. I have attempted to apply the idea to saline matters; but as we are still but imperfectly acquainted with the nature and the combinations of the fluoric and the boracic acids, I have applied it only to the sulphuric, the nitric, the muriatic, and the carbonic acids, considered in relation to the mineral saline bases, and the degrees of adhesion which they appear to have with these bases. The numbers which I have employed to express the different degrees of adhesion, are founded on the result of simple decompositions. Perhaps they do not express accurately the force of affinity; but the design of employing

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playing them is only to show the cause of double affinities.

I will first give a table, expressing in numbers the affinities of the four acids with six bases; not including barytes, because we are not yet well enough acquainted with the various saline combinations into which that substance enters. Afterwards, I shall lay down in particular tables the double affinities known to subsist among the neutral salts; adopting Bergman's mode of arrangement, which I have already described under the article of affinities in general. I may here observe, that in this ingenious arrangement, to which the only addition that I have made is expressing the affinities in numbers, the sum of the two vertical numbers which indicate the divellent attractions, is to be considered as standing in opposition to the sum of the horizontal numbers which indicate the quiescent attractions; which opposition of attractions is the cause of the decomposition effected by double affinity.

TABLE of the Degrees of Attraction between four Acids and six Bases, expressed in Numbers.

C O L U M N F I R S T.

The sulphuric acid combines with	Potash, with an affinity equal to	-	8
	Soda	- - - - -	7
	Lime	- - - - -	6
	Ammoniac	- - - - -	4
	Magnesia	- - - - -	3½
	Aluminous earth	- - - - -	2

C O L U M N

COLUMN SECOND.

The nitric acid combines with	{	Potash, with an affinity equal to	-	7
		Soda	-	6
		Lime	-	4
		Ammoniac	-	3
		Magnesia	-	2
		Aluminous earth	-	1

COLUMN THIRD.

The muriatic acid combines with	{	Potash, with an affinity equal to	-	6
		Soda	-	5
		Lime	-	3
		Ammoniac	-	2
		Magnesia	-	1
		Aluminous earth	-	1

COLUMN FOURTH.

The carbonic acid combines with	{	Lime, with an affinity equal to	-	3
		Potash	-	2
		Soda	-	1
		Ammoniac	-	$\frac{1}{2}$
		Magnesia	-	$\frac{1}{3}$
		Aluminous earth	-	$\frac{1}{4}$

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A TABLE exhibiting ten Kinds of double Affinity which take place among the several Neutral Salts, in Numbers taken from the preceding Table.

I.

Nitre.

Sulphate of potash.	Potash.	7	The nitric acid.	Calcareous nitrate.
	8 quiescent	divellent affinities 4	{ 12 *	
	The sulphuric acid.	6	Lime.	
	13			
Calcareous sulphate.				

II.

Muriate of potash.

Sulphate of potash.	Potash.	6	Muriatic acid.	Calcareous marine salt.		
	8 quiescent	divellent affinities	affinities 3		{ 11	
	The sulphuric acid.		6			Lime.
	12					
	Calcareous sulphate.					

III.

* The number placed on the right side, between the small and the large bracket, is the sum of the two horizontal or *quiescent* affinities; and the decomposition cannot take place unless this sum be less than that of the two *divellent* affinities. A.

III.

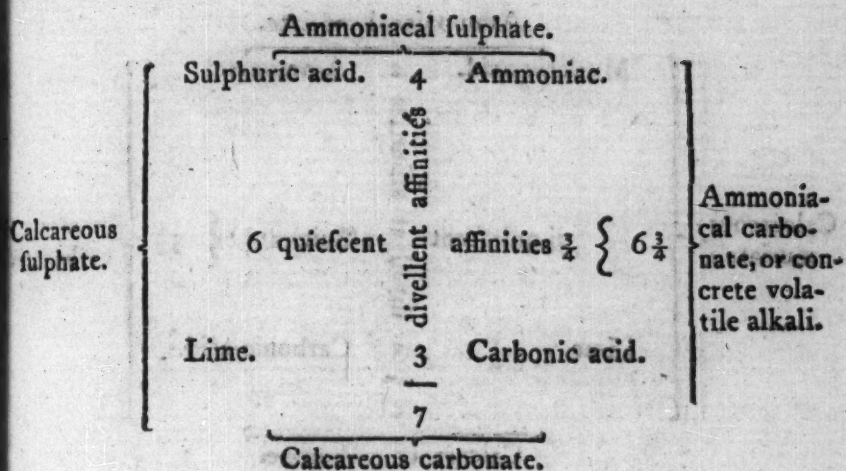
		Nitrate of soda.	
Sulphate of soda	Soda.	6	Nitric acid.
	divellent affinities		
	7 quiescent	affinities 4	{ 11
		Calcareous Nitrate.	
Sulphate of soda	Sulphuric acid.	6	Lime.
	12		
	Calcareous sulphate.		

IV.

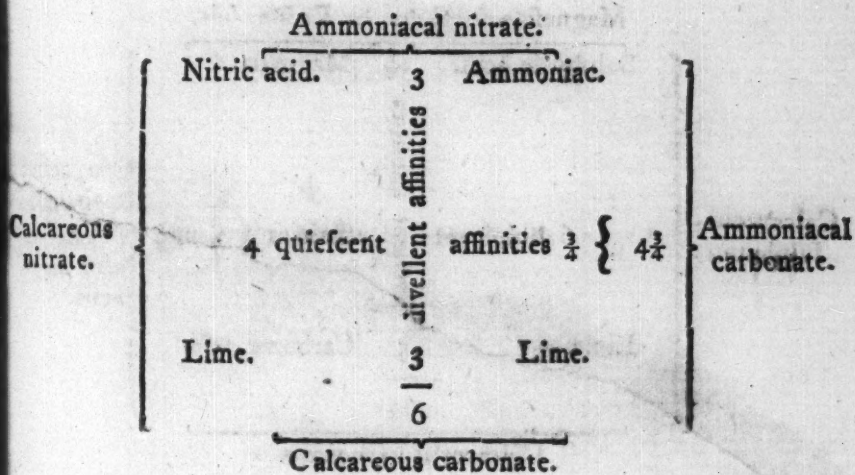
		Muriate of soda.	
Sulphate of soda	Soda.	5	Muriatic acid.
	divellent affinities		
	7 quiescent	affinities 3	{ 10
		Calcareous muriate.	
Sulphate of soda	Sulphuric acid.	6	Lime.
	11		
	Calcareous sulphate.		

Salts.

V.



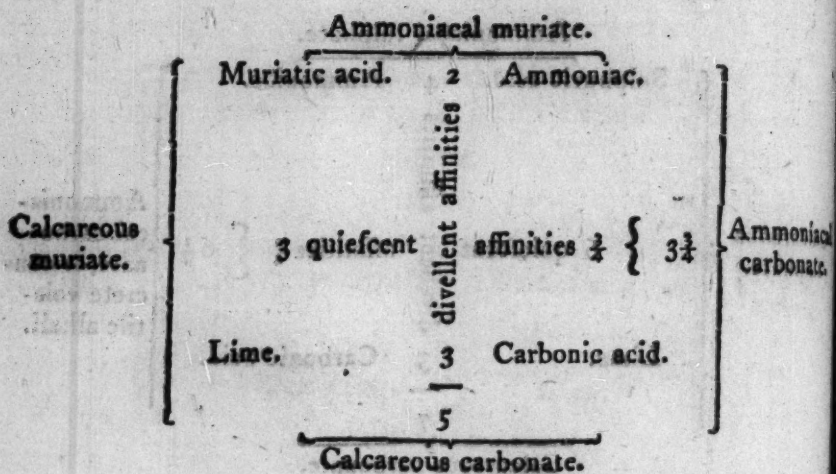
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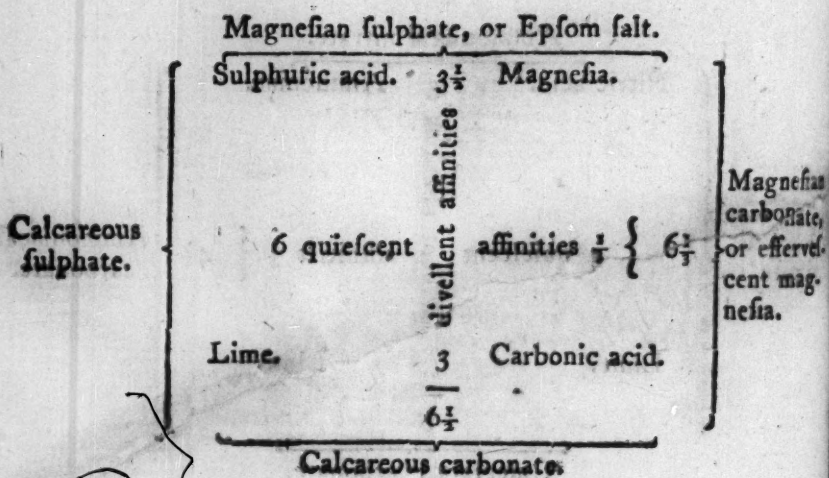
VII.

Salts.

VII.

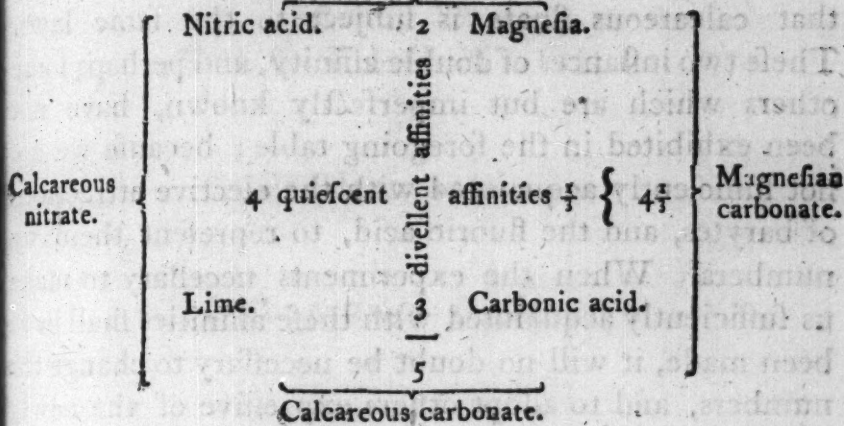


VIII.



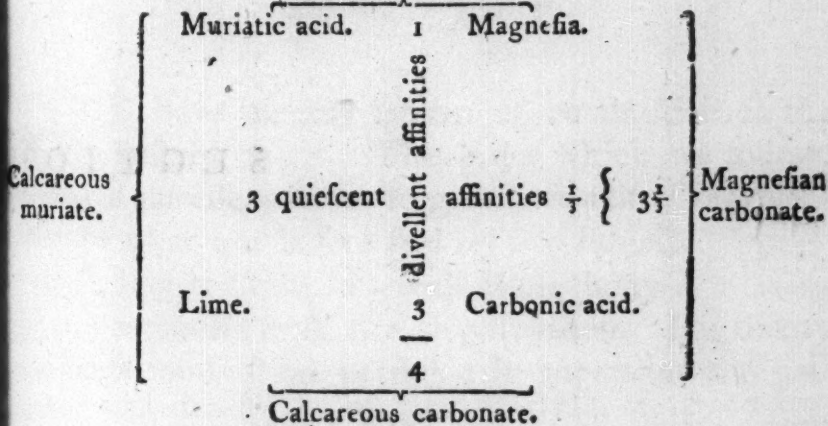
IX.

Magnesian nitrate.



X.

Magnesian muriate.



These ten are not the only affinities subsisting among the neutral salts which we have examined. We have seen, for instance, that the barytic salts are not decomposed by potash, but are liable to decomposition by carbonate of potash, or carbonate of soda; and that calcareous fluuate is subject to the same laws. These two instances of double affinity, and perhaps some others which are but imperfectly known, have not been exhibited in the foregoing table; because we are not sufficiently acquainted with the elective attractions of barytes, and the fluoric acid, to represent them by numbers. When the experiments necessary to make us sufficiently acquainted with these affinities shall have been made, it will no doubt be necessary to change the numbers, and to adopt others expressive of the newly discovered affinities: But the method will still remain; it can only be rendered more accurate.

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SECTION III.

Of MINERALOGY.

Combustible Bodies.

CHAP. I.

Of Combustible Bodies in general.

WE have already spoken of combustion in the history of air. The order which we follow, renders it necessary for us to give here a brief recapitulation of what was before said on this subject.

According to Stahl, a combustible body is a compound containing fixed fire or phlogiston. His theory represents combustion as the disengagement and passage of this fire from a fixed into a free state. Light and heat are signals indicating its disengagement. When the phenomenon ceases, the body which has displayed it enters into the class of incombustible mat-

ters: by restoring its phlogiston, or by uniting with it the matter of fire fixed in some other body, we render it again combustible. But this theory is attended with four material difficulties. 1. The existence of phlogiston cannot be demonstrated. 2. The weight of combustible bodies is constantly found to be increased after combustion; and it is hard to conceive how this can happen to any body when it loses one of its principles. 3. Another strange circumstance is, that any body should lose part of its weight, by that accession of phlogiston which causes it to pass from an incombustible to an inflammable state. 4. Stahl does not appear to have considered that air is necessary to combustion.

A more careful observation of the last of these phenomena, and of the increase of weight which bodies acquire during their combustion, has given rise to the following theory.

What renders a body combustible is its having a strong tendency to combine with the oxygenous principle, which is the base of vital air. Combustion is the very act by which this combination takes place; it never happens but when the oxigene loses the caloric by which it was maintained in a gaseous state. This opinion is founded on the four following facts: 1. No body can burn without vital air. 2. When the air is purest, the act of combustion is then most rapid. 3. By combustion air is absorbed, and the burnt body gains additional weight. 4. Lastly, A body burnt in the air acquires a quantity of oxigene equal in weight to what the surrounding atmosphere loses; which oxigene may be often extracted by methods which we shall hereafter describe.

Macquer attempted a reconciliation of this theory

with Stahl's, by explaining phlogiston to be light in a fixed state, and ascribing to vital air the power of precipitating light. He thought, that in every act of combustion, phlogiston was separated into the state of light by vital air, which occupied its place in the combustible body; and he considered light and vital air as two substances which mutually precipitated each other. When fixed light is caused to pass out of a combustible body into a body that is already burnt; the vital air, according to this theory, yields its place in the one body to light, and seizes that which the light has left unoccupied in the other. But within these few years, the chemical doctrine on this head has attained a degree of strictness and accuracy which neither requires nor allows our having recourse to such forced and complicated theories. We may here recapitulate it, in order to represent it with still more plainness and perspicuity than before.

Vital air is compounded of a base named *oxigene*, which is susceptible of fixation, and is maintained in solution in the state of an elastic fluid by light and caloric. When a combustible body is heated in this fluid, it decomposes the vital air, and seizes its base or *oxigene*. The caloric and light being then set at liberty, regain their original rights, and escape in possession of all their distinguishing properties; namely, the first in the form of heat, the second in the form of flame. According to this doctrine, vital air is the only combustible body. This theory does not absolutely deny the existence of a phlogistic principle; for light acts the part which was ascribed to it. But it differs from Stahl's theory, in representing the phlogiston which he placed in the combustible body, as a principle not of it, but of the body by which combustion is maintained. The same

objection may indeed be made against the existence of oxigene which has been urged against Stahl's phlogiston. We are entirely unacquainted with any such principle in a pure or insulated state: it is always combined with caloric in vital air, or with combustible bodies after they have suffered combustion. Like phlogiston, it only passes from one combination into another; but never displays itself in a pure separate state. There is, however, a mighty difference between the two theories. The latter, to which we ascribe truth and accuracy, is founded upon plain facts; the increase of weight which a combustible body gains, and the diminution of weight which the surrounding atmosphere suffers from combustion; whereas ingenuity has never been able to establish Stahl's theory on such a basis.

Combustible bodies differ in their tendency to combine with oxigene; and it would appear that a body is more or less combustible, according as it has a nearer or a more distant relation to this principle. So that the order in which combustible bodies tend to combustion may be determined, and a table constructed to express their various affinities with the base of vital air.

This difference of affinity between combustible bodies and oxigene is the cause of that diversity of phenomena which such bodies exhibit when they enter into combination with this elastic fluid.

We may distinguish four different kinds of combustion.

1. Combustion with flame and heat, as in the instance of sulphur, &c.

2. Combustion with heat without flame, as in many of the metals, &c.

3. Com-

3. Combustion with flame without heat, as in phosphori, &c.

4. Slow combustion, apparently without either flame or heat; which happens when certain combustible bodies are brought into contact with air, or when oxigene fixed in some body, and separated from caloric, passes unobserved out of that body into another.

Besides these leading distinctions, combustion is varied by many other phænomena, peculiar to particular combustible bodies. The velocity, the colour, and the extent of the flame, the smell which accompanies it, the quantity of oxigene absorbed, the form, the colour, and the weight of the residue of the burnt body, with many other particulars, which it would be improper to enlarge upon here, but which shall be considered with all the attention they merit, when we give the history of each combustible body by itself, form so many essential distinctions, by means of which combustible substances may be distributed into classes.

When we consider all the varieties which combustible bodies exhibit during their combustion, we cannot avoid agreeing that the causes from which they proceed are still unknown; and there are still important discoveries to be made on this article of the theory of chemistry. The different affinities of combustible bodies with the oxygenous principle, may serve to explain a part of the phænomena. Indeed it is natural to think that a body having a strong tendency to combine with this principle, must afford most heat, motion, and light, when the combination takes place; because such a body will separate oxigene from vital air in a more forcible manner than any other whose tendency to combine with it is weaker. But yet this doctrine does not account for the diversity of colour which distinguishes the flame that proceeds

from different inflammable bodies; why, for instance, copper gives a green flame, &c. Neither does it explain, not at least in an experimental way, why some combustible matters burn without giving out any apparent flame, unless we agree with some philosophers, that light and heat are the same, only the one in a more attenuated, the other in a more condensed state. But it is well known with what difficulties this opinion is attended. If we reflect, that light is one of the principles of vital air, and is disengaged during combustion, we may perhaps be induced to think, that this body is disengaged in a different manner by different combustible matters: that, in some instances, the whole of light, consisting of seven rays or principles, is completely disengaged; while in others, as when nitrous gas acts on combustible bodies, only the orange ray is separated; and in others, the green, or yellow, as when zinc and copper act on combustible bodies. But this hypothesis, which has been already mentioned in the history of combustion under the article of Air, is still unsupported by experiments. It is enough that it is almost demonstratively proven, that the light disengaged by combustion exists not in the combustible body, but in vital air. How indeed can we imagine, that a body so much attenuated, and so elastic as light, should be susceptible of fixation and solidity? Is not it more natural, and more consistent with sound philosophy, to think that light, instead of being susceptible of solidity, must rather possess the property of destroying the solidity of solid bodies; and that it is one of the causes of the elasticity of vital air, which is nothing but a combination of oxigene, which in a separate state is solid, with the caloric principle, and with light?

There

There are, therefore, still a few difficulties to resolve in the history of combustion: But it is now sufficiently proven, that combustible bodies, on being burnt, undergo a total change of nature; that the oxigene which becomes fixed in them, in consequence of their combustion, always increases their absolute weight; and that this principle then assumes a more solid form, than when, in combination with caloric and light, it constituted vital air.

We divide the combustible matters of the mineral kingdom into five genera; namely, diamond, hydrogenous or inflammable gas, sulphur, metallic, and bituminous matters.

C H A P.

CHAPTER II.

Genus I. *Diamond.*

DIAMOND is a substance of a peculiar kind ; it is ranked among stones, because it possesses their hardness, insipidity, and insolubility. It is, besides, the most transparent, and the hardest of minerals. It is so hard, that the best tempered steel is incapable of penetrating it ; nor can diamonds be cut by any other means but by rubbing them on one another.

Diamonds are found in the East Indies, particularly in the kingdoms of Golconda and Visapour. We likewise get them from Brazil ; but the Brazilian diamonds appear to be of an inferior quality : they are known in commerce by the name of *Portuguese diamonds*.

Diamonds are commonly met with in an ochreous yellowish earth, beneath rocks of grit-stone and quartz ; sometimes, too, they are found in the beds of rivers : those found in this situation have been carried off by the stream from diamond mines. Diamonds are seldom
above

above a certain size. The Indian monarchs keep up the largest of them, to hinder their price from falling. Diamonds do not display all their lustre immediately after being taken out of the earth; they are brilliant only when found in water. All that are dug from mines are covered with an earthy crust; and when it is taken off, they exhibit, according to M. Romé de Lille, a second, of the same nature with calcareous spar.

Diamonds have often an irregular form, and are either flat or round. Sometimes they exhibit regular octohædral crystals, consisting of two quadrangular pyramids, joined at the base; they are likewise found with 12, 24, and 48 faces.

Some diamonds are perfectly transparent, and of the finest water; there are others spotted, veined, clouded; these are much less valuable than the former. Some, again, are uniformly and deeply tinged with yellow, red, blue, or black; but these are very rare.

Diamonds appear to consist of laminæ, disposed one over another. They are easily split, by striking them with an instrument of well-tempered steel. But there are some diamonds which appear to consist not of laminæ, but of fibres interwoven, so as to resemble the knots of wood. These last are so very hard, that they cannot be wrought; the lapidaries call them *natural diamonds*.

The transparency and hardness of the diamond, and the regular crystalline form which appears to be most natural to it, induced naturalists to rank this substance among vitrifiable stones. They considered it as the matter of the purest and most homogeneous rock-crystal. They thought it unalterable by fire; because when jewellers heat diamonds spotted with yellow, even

even till they become red, the spots are indeed converted to black, but the lustre of the stone is not diminished. Yet diamond was known to be more ponderous and harder than rock-crystal, and to possess electrical properties in a very eminent degree. But these peculiarities were ascribed to its extreme purity.

All transparent, stony, or saline bodies, are known to refract light in the direct ratio of their densities; but combustible bodies refract light in the double ratio of their density. The peculiar brilliancy of the diamond appears to depend on its capacity of refracting light in so eminent a manner. As it is so highly transparent, and light is so strongly refracted between its laminæ, when its surfaces are multiplied by cutting, each of its facets affords a sheaf of very splendid light. And therefore those diamonds which are cut into facets all over their circumference, have a much superior lustre to those which are cut only on one side. On this account, lapidaries give the first the name of *brilliants*, while they call the others *roses*.

Boyle asserted that fire altered diamonds, and disengaged from them acrid vapours; but this fact did not immediately engage the attention of philosophers. But in the years 1694 and 1695, Cosmo III. Great Duke of Tuscany, saw the substance of diamond entirely destroyed by the heat of a burning-glass. The Emperor Francis I. likewise witnessed at Vienna the destruction of diamond by the fire of a furnace.

M. d'Arcet, in his valuable experiments on stony matters exposed to a violent and continued heat, has not neglected diamonds. He informs us, that vapours issue from the sides of their laminæ; and that if this evaporation be caused to cease, what remains of the
diamond

diamond is found to have suffered no alteration of nature, but a diminution of bulk.

M. d'Arcet, wishing to know whether the evaporation of diamond was simply a decrepitation, contrived to treat it in vessels variously closed. He took a sphere of porcelain paste, and after cutting it into halves, put a diamond in the middle; he then joined the two sections nicely together, so that the diamond formed to itself a cavity within the sphere, without leaving any void space around it. Putting those balls into an oven, and leaving them there till they were fully burnt, he then broke them, and found the diamond evaporated, and the place which it occupied empty, tho' he could perceive no chink or fracture any where over the surface of the ball.

M. d'Arcet varied this experiment many ways; using sometimes balls of porcelain paste, sometimes crucibles of burnt porcelain, stopped at the mouth with the same matter, and coated over with a fusible substance; which being vitrified by fire, sealed the vessel hermetically. M. d'Arcet always found the diamond to disappear; and inferred, that it was susceptible of evaporation without the help of air.

Messrs d'Arcet and Roux have since observed, that so intense an heat is by no means necessary to effect the volatilization of diamond: And in the year 1770, M. Roux volatilized a diamond in the medical schools in five hours, in a cupelling furnace.

In the year 1771, Macquer observed a new phenomenon relative to the destruction of this substance. He made use of Pott's furnace, on which he had made several improvements in volatilizing a diamond. This furnace, when fitted with a pipe or chimney, ten or twelve feet high, produces an heat equal to that of a fur-

furnace for hard porcelain. Macquer put a muffle in the middle of his furnace, and the pipe which was fitted to it was only two feet long. He put a diamond, cut into a brilliant, and weighing three-sixteenths of a carat into a cupel, which he at first placed near the mouth of the red-hot muffle; and to prevent the diamond from bursting into pieces, he put the cupel containing it, not at once, but gradually, into the muffle. On observing the diamond at the end of twenty minutes, he found it to have increased in bulk, and become much brighter than the capsule in which it was placed. At last he observed a kind of lambent phosphoric flame, which glowed in a very distinct manner around the stone; but he could not perceive any of those acrid vapours which Boyle mentions. The diamond being replaced in the muffle, disappeared entirely at the end of thirty minutes, so as to leave no vestige of it behind. Thus Macquer, in less than an hour, volatilized a diamond weighing nearly four grains; and observed, that the combustion of this, like that of other combustible bodies, is attended with a discernible flame.

This fact, which was first communicated to the world by Macquer, has been since confirmed by repeated trials. M. Bucquet in the year 1775 volatilized a diamond of about three grains and an half. He made use of Macquer's furnace, but without the pipe; and the muffle was left open during all the time of the operation, in order that what passed during the combustion of the diamond might be seen. It continued about five minutes without being inflamed, and the space between the instant of its inflammation and its being totally volatilized was five-and-twenty minutes.

As none of these experiments showed what became

of the diamond, Messrs Macquer, Lavoisier, and Cadet, resolved to make some new experiments on this substance in close vessels. They distilled twenty grains of diamond in a stone retort, fitted with an apparatus proper for retaining the products, if there should be any. They exposed it to the utmost violence, without obtaining any product. After the operation, they found the diamonds pretty entire, yet not quite so heavy as before. From this circumstance, they suspected that this loss of weight was owing to the diamonds being partly burnt, with the help of the small portion of air contained in the vessels: the diamonds were, besides, covered over with a blackish and seeming carbonaceous crust, which soon disappeared when they were rubbed on a grind-stone.

While chemists were employed in experiments on the nature of the diamond, the lapidaries always thought it absolutely indestructible. M. le Blanc, one of these artists, took a diamond to M. Rouelle to expose it to fire, but insisted on inclosing it in a way of his own. Accordingly, he put it into a crucible, with a cement of chalk and coal reduced to powder. This crucible was inclosed in another, which was closely covered and luted with founder's sand. It was then put into the fire, and left exposed to it for four hours. At the end of that time, both M. le Blanc's diamond and others which M. Rouelle had exposed to the fire were vanished. M. Maillard, another lapidary, waited on M. Cadet, when Messrs Macquer and Lavoisier were engaged with him in experiments on this substance, bringing with him three diamonds, which he proposed to expose to fire after cementing them in his own way. He pressed the bowl of a tobacco-pipe full of pounded charcoal, and putting his diamonds in the middle, covered the
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pipe with an iron plate, which he luted to it with founder's sand. The pipe was put into a crucible lined with chalk, and coated over with sand wet with salt water. The whole was put into Macquer's furnace, and exposed to such an heat, that at the end of two hours the apparatus was become soft and ready to melt. The crucible was now vitrified, and had lost its shape. It was cautiously broken, and the pipe was found whole: the charcoal within it was perfectly black, and the diamonds had lost nothing. They were only a little blackened on the surface; but they recovered their whiteness and lustre on being rubbed on a grind-stone. Macquer repeated this experiment with the same success in the great furnace in which the hard porcelain of Seves is burnt. But, on this occasion, part of the iron which covered the pipe having been melted, it had reached the diamond, and scorified it on one side; but the other was perfectly unaltered. The fire had been kept up for four-and-twenty hours.

M. Mitouard having had occasion to expose several diamonds to fire in close vessels, and with various cements, observed, that charcoal was more effectual for preventing the combustion of this body than any other matter.

From these facts, all chemists were led to think, that diamond burns like other combustible bodies; and that, like charcoal, it cannot be destroyed by fire without being in contact with air. Yet the numerous and accurate experiments of M. d'Arcet appeared to establish a contrary doctrine. To determine this matter, Macquer filled several bowls of burnt porcelain, and several crucibles of porcelain paste with powder of charcoal. In the crucibles of unburnt porcelain the charcoal was reduced to ashes, and the ashes were even

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vitriified; but in the vessels of burnt porcelain the charcoal appeared to have suffered no alteration: and he thence concluded, that there is a great difference between these two kinds of vessels. He thinks, that while porcelain is burning chinks are produced in it, which though scarce discernible, are sufficient to facilitate combustion; and that, as the porcelain shrinks in when it cools, all the chinks are closed up, and disappear after it is burnt.

To these, M. Lavoisier has added new experiments, proving, that diamond does not burn unless it be in contact with air. He exposed diamonds to the focus of M. de Trudaine's lens, after covering them with a bell, into which he made water or mercury rise by emptying it of air. This chemist, in experiments on the effects of the burning-glass, which he made in conjunction with Messrs Macquer, Cadet, and Briffon, had already observed, that when diamonds are suddenly exposed to a strong heat, they crackle and scintillate; which never happens when they are slowly and gradually heated. He likewise observed the diamonds to melt in some parts of their surface; such of them as were for some time exposed to the heat of the lens were penetrated all over their surface with small holes, like a pumice-stone. When he heated them in the pneumatological machine above described, he was convinced, that the diamond burnt only for a certain time, in proportion to the quantity of air contained in the bell-glass. He examined the air in which the diamond had burnt, and found it precisely similar to that which remains after the combustion of any other combustible body; that is, it had lost that proportion of vital air which renders atmospheric air fit for combustion. One circumstance which deserves to be taken notice of is,

that the air which remained after the combustion of diamond precipitated lime-water, and contained carbonic acid.

In order to determine with still greater certainty the nature of diamond, M. Lavoisier attempted to burn it under a bell-glass filled with carbonic acid. The diamond suffered some loss, which was owing no doubt to a portion of air mixed with the acid. He is also of opinion, that the loss which diamond suffers on such occasions is owing to its being volatilized: and he infers from this instance, that this body may be entirely volatilized, if it be inclosed in a close vessel, and a strong enough heat applied to it. M. Lavoisier having submitted charcoal to the same operation, obtained a similar result, in regard both to its combustion and its volatilization. He observed too, that the surface of diamond always becomes black.

From these facts it follows, that diamond is a substance very different from stones; that it is actually a combustible body, which burns with flame whenever it is made red hot in contact with air: In a word, that it is a volatile combustible body, for diamond never leaves any fixed residue; and that it perfectly resembles charcoal in the manner in which it is affected by fire; though very different from it in transparency, gravity, hardness, and many other properties. All of the above experiments, as well as the art of splitting diamonds, show, that this body consists of laminae, or layers arranged one over another; that there is sometimes between the layers an extraneous colouring matter, to which the carbonaceous coating with which ignited diamonds are covered, especially when in close vessels, is possibly owing. This coloured layer, which is sometimes nearer to, and sometimes more remote from, the surface.

surface, often defeats the attempts of the lapidary to whiten spotted diamonds. If it be near the surface, it is easy to destroy it, and render the diamond entirely white. But when it is sunk deep within the body of the diamond, it is impossible to remove it, without destroying successively the laminæ by which it is covered: and in that case, a diamond will be sometimes entirely destroyed before it lose its colour.

Notwithstanding all these experiments, we know not yet of what principles diamond is composed: in the present state of our knowledge, it is to be considered as a peculiar combustible body, different from all others.

Diamond is of no use but as an ornament: but its property of refracting the rays of light, of decomposing them, and exhibiting to the eye the most brilliant and lively colours, renders it so truly valuable, that the esteem in which it is held is not to be attributed to the caprice of fashion. Its value is farther increased by its excessive hardness, which enables it to retain the polish, its scarcity, and the ingenious art with which it is cut. It is used for engraving on glass and on hard stones, and to cut these bodies into any required form and size.

Diamond-powder is used for grinding and polishing whole diamonds.

C H A P. III.

Genus II. *Hydrogenous Gas.*

WHAT Dr Priestley calls *inflammable air*, and we *hydrogenous gas*, is an aeriform fluid, possessing all the apparent properties of air. It is about thirteen times lighter than common air; it does not contribute to maintain combustion, and it is almost instantaneously fatal to animals by throwing them into high convulsions. It has a strong smell. One of its characteristic properties is, to take fire when, being in contact with air, an inflammable body is brought near it, or the electric spark caused to pass through it.

Hydrogenous gas has been long known both in nature and art. Metal, and coal mines, the surface of masses of water, and animal or vegetable matters in the state of putrefaction, afford many instances of natural, combustible vapour. Art has laboured to produce similar vapours, by dissolving metals with the sulphuric and muriatic acids, and by distilling animal and vegetable substances. But, before Dr Priestley

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ley, no person thought of collecting those vapours in receivers, in order to examine their properties. He discovered that they constitute a kind of permanent elastic fluid.

Hydrogenous gas displays all the phænomena characteristic of combustible bodies in a very eminent degree. Like them, it does not burn but when in contact with air: when pure, it burns with a flame which is more or less red; it gives a blue or yellow flame when combined with any substance capable of modifying its properties. It often crackles, and gives out, when burning, small bright sparks, with a noise similar to that which is produced by the detonation of nitre. It produces, when burning, a lively heat. It is kindled by contact with the electric spark.

It burns with the greatest rapidity when it is surrounded with a great quantity of air. As the aggregation of the two fluids is the same, it is possible to mix them so, that a particle of hydrogenous gas shall be involved among particles of air; and it then burns with great rapidity. This happens when a mixture, consisting of two parts of atmospheric air and one of hydrogenous gas, is inflamed. The mixture kindles, burns in an instant, and produces a smart explosion like that of gun-powder: but again, hydrogenous gas by itself burns but slowly, and only at the surface.

It may likewise be made to burn in an instant, and with great violence, by mixing two or three parts of it with one of vital air or oxygenous gas: it then produces a much greater explosion than in the above instance.

Mr Cavendish some years ago observed, that when-

ever hydrogenous gas is burnt, drops of water always appear. On burning this gas in a vessel filled with vital air above mercury, a vacuum is produced in the vessel, the mercury rises, and great drops of very pure water are seen to trickle down the sides of the vessel, their quantity still increasing as the combustion goes on. M. Lavoisier combined such a quantity of these two elastic fluids as afforded several drams of water. He took care to make both the fluids pass through a glass cylinder, filled with dry caustic fixed alkali, in order to purify them entirely from any portion of water which might be intermixed with them. The weight of the water obtained answered exactly to that of the elastic fluids consumed. And he concluded from this experiment, that water is actually a compound of these two fluids, in the proportion of six parts of oxygen to one of hydrogen. For it is easy to understand, after what has been already laid down, that the caloric and the light of vital air, and hydrogenous gas, are disengaged during their combustion. And the disengagement of these principles accounts for the weight of water being so very different from that of oxygenous or hydrogenous gas. The gravity of water is to that of hydrogenous gas in the proportion of 11,050 to 1, if we suppose the levity of this gas to be to that of atmospheric air in the proportion of 13 to 1: The disparity will be still greater, if the levity of hydrogenous gas be estimated at 16, which may be fairly done when it is perfectly pure.

Water obtained by the combustion of vital air with hydrogenous gas is found to contain some grains of nitric acid. In order to understand how this acid is formed, we may reflect, that Mr Cavendish produced

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nitric gas by combining, through means of the electric spark, seven parts of vital air with three of azotic gas from the atmosphere.

But the vital air which M. Lavoisier made use of for his experiment was extracted from red precipitate, or mercurial oxide precipitated by the nitric acid; and that oxide might perhaps afford the small portion of azote which enters into its composition: wherefore the nitric acid obtained in this experiment is not to be considered as in any degree falsifying the assertions of M. Lavoisier concerning the production of water. If with this fine experiment we compare that by which the same chemist decomposed water, by making it fall on red iron, zinc, and coals, as well as boiling oils, and obtained a quantity of the hydrogenous gas proportioned to the quantity of the body burnt, we will find good reason to conclude, that the theory of the composition of water is as well supported as any other chemical theory.

The proportion in which the component principles of water are united in it, appears from the most accurate experiments to be 85 parts of oxigene to 15 of hydrogenene in weight.

We want only one thing, to know the nature of hydrogenous gas. Is it a simple substance, or a compound subject to no varieties, but always the same in species? May it be considered as the phlogiston of Stahl, which several English chemists, at the head of whom is Mr Kirwan, think it to be?

With regard to the first question, it is nearly agreed among chemists, that all substances, however different in nature, which contain inflammable gas, afford it precisely the same in all its properties.

There are indeed some who still acknowledge several

ral species of inflammable gas; such as the inflammable gas obtained from iron and zinc by water, which burns with a red flame, and detonizes with pure air; that which M. de Laffone obtained from Prussian blue, and from the reduction of flowers of zinc by charcoal, which burns in air without detonization; the inflammable gas that rises from marshes, and burns with a blue flame, without detonization; and that which is obtained by the distillation of organic matters, and resembles the gas of marshes. But we have learned from a strict analysis of the two last, that they are compounds of genuine, pure, and detonating hydrogenous gas, with azotic gas or carbonic acid in various proportions. In the year 1782, I was led to think, with the illustrious Macquer, that there is only one substance of this kind, which, by combining with different substances, undergoes various modifications. The experiments of many celebrated natural philosophers, particularly of Cavendish, Priestley, Wath, Kirwan, Lavoisier, Monge, Berthollet, de Morveau, &c. have since established the truth of this opinion. The mixtures of the other gases, and the solution of coal, sulphur, and phosphorus in hydrogenous gas, the weight of which they augment, and render it less combustible, afford us reason to think, that the seeming varieties of inflammable gas are owing to such mixtures or combinations. To me therefore it appears to be at present fully demonstrated, that there is only one species of inflammable gas, produced by the decomposition of water, and capable of producing water by combining with vital air; in a word, that there are no species belonging to this genus but hydrogenous gas, which is more or less inflammable, and variously coloured,

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loured, according as it is mixed or combined with other bodies.

As to the second question; there are indeed several facts which appear to support the opinion of Bergman and the English chemists, who take hydrogenous gas to be Stahl's phlogiston: but there are many more which oppose our adopting that opinion. It appears that the combustible substances in which Stahl allowed the existence of phlogiston, do not all afford this elastic fluid, and that water always contributes to its formation. Mr Kirwan, who has been engaged for several years in examining this important question, has not yet, as far as we know, been able to determine it by any decisive experiment. Under some other articles of this work we will give our opinion of the hydrogenous gas, which that celebrated chemist obtained from an amalgam of zinc, as well as of some other analogous experiments, which have been urged by several philosophers against the doctrine which we advance. We will not here enter into a detail of the objections which may be made to it; for we might possibly not be understood by those whose studies in chemistry have not extended farther than the foregoing chapters of our work: but those objections shall be stated in the chapters concerning metallic substances, phosphorus, &c. However it be, we must here acknowledge the phenomena may be explained on the supposition that hydrogen is the same with phlogiston; but we cannot help observing, at the same time, that the theory of phlogiston requires to support it some forced and improbable suppositions, and is far from being equally simple and satisfactory with that which we have adopted as the plain simple result of facts*.

No

* See Mr Kirwan's work on this subject; or the French translation of that work, with the notes added.

No chemist has yet analysed hydrogenous gas into principles: it is to be considered as a simple substance in the present state of our knowledge: hydrogen, its base, combines entirely with pure air, or oxigene; and water is formed by the combination. The reader will observe, that we have said nothing of the theories of those writers, some of whom have asserted inflammable gas to be a compound of air with the matter of fire, while others represent it as a modification of light, fire, the electric fluid, &c. These assertions are too vague, bear too great a resemblance to the inaccurate and ambiguous language of the infancy of natural philosophy, and are too inconsistent with experiments, to merit a serious discussion. Hydrogenous gas, no doubt, contains a good deal of specific heat or caloric, perhaps even of the matter of light; nor is it always separated from these gaseous matters whenever it loses its state of elasticity, and passes into liquid combinations.

Hydrogenous gas does not combine with water; it may be long kept under that fluid, without suffering any alteration. At length, however, it is so much altered, as to be no longer susceptible of inflammation. Dr Priestley has not determined the nature of this change, nor the state of the water which produces it. Probably, if such an experiment were carefully performed, it would throw much light on the nature of this combustible body.

Hydrogenous gas is not known to act either on earths or on any of the three salino-terreous substances; but it destroys the whiteness of barytes, and communicates to it a colour; which has caused it to be considered as the calx or oxide of some metal still unknown.

We know not what effects the alkalis and the acids

are

are capable of producing on this gas, nor what changes it produces on them. It would probably decompose some acids, particularly the sulphuric acid and the oxygenated muriatic acid, by combining with their oxygen to form water. As to the sulphuric acid, there is reason to think it liable to such a decomposition; for as sulphur does not decompose water (a fact of which we will afterwards have occasion to take notice), the base of vital air has certainly a stronger affinity with hydrogene than with water. The oxygenated muriatic acid has so considerable an excess of oxygen, and that so imperfectly united with it, that we may with good reason think that hydrogenous gas would carry off part of it to form water.

Hydrogenous gas does not seem capable of acting on neutral salts; but its influence on saline substances in general has not yet been examined.

This gas is become a substance of much more consequence than formerly, since it has been made use of to fill aerostatic machines: a discovery which we owe to Messrs Montgolfier. Its specific levity, which is thirteen times greater than that of air, causes those machines to rise in the atmosphere. It is more than probable that it performs an important part in all the phenomena of meteors; that there is a great quantity of it diffused through the atmosphere; and that the electric spark kindles it, and causes it to produce water. Perhaps it is carried about in the winds as a kind of natural aerostatic.

Attempts have been made to substitute it in the room of other combustible matters for some of the purposes of life; to give light and heat, and to discharge fire-arms, &c. M. Volta has considered it in this last point of

of view, and has proposed several ways of making use of it. M. Nerete, in the *Journal de Physique* for January 1777, has given a description of a chaffing-dish with inflammable gas. M. Furstenberger, a natural philosopher at Bale, M. Brender, an ingenious mechanic of Augsburgh, and M. Ehrman Lecturer in Natural Philosophy at Strasburgh, have contrived lamps which may be kindled at night by means of the electric spark. Lastly, Artificial fires, affording a very agreeable spectacle, are made with glass tubes, variously bent, and pierced with a great many holes. Inflammable gas is introduced into these tubes from a bladder full of it, through a copper cock. When the bladder is pressed, the inflammable gas passes into the tube, issues out thro' all the holes, and is kindled by a burning taper.

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Genus III. *Sulphur.*

SULPHUR is a combustible body; dry, very brittle, of a citron yellow colour, entirely without smell, except when it is burnt, and of a peculiar taste, which is weak, though perceptible enough. When rubbed, it becomes electric. When a large piece of it is exposed to a moderate but sudden heat, as for instance, by being compressed in the hand, it crackles and breaks into pieces.

Sulphur abounds in nature; sometimes it is found pure, and sometimes in combination with other substances. It is our business here to speak only of the former. The following are the varieties of pure sulphur.

Varieties.

1. Transparent sulphur in octohædral crystals, with two truncated pyramids. It is generally de-

Varieties.

deposited by water on the surface of a calcareous spar. Cadiz sulphur is of this kind.

2. Transparent sulphur in irregular fragments. The sulphur of Switzerland is in this state.
3. Whitish pulverulent sulphur, deposited in filiceous gæodes. There are flints found in Franche-Comté, &c. full of sulphur.
4. Pulverulent sulphur, deposited on the surface of mineral waters; such as those of Aix-la-Chapelle, of Enghien near Paris, &c.
5. Crystalline sulphur that has been sublimated; the crystals are transparent: it is found in places adjacent to volcanoes.
6. Pulverulent sulphur sublimated by volcanoes; its form is irregular, and it is often intermixed with soft stones, as may be observed at Solfatara, in the neighbourhood of Naples.
7. Sulphur in stalactites, formed by volcanic fires.

Besides these seven varieties of pure mineral sulphur, this substance is found in combination with various other matters. It is most frequently united with metals, which are then in the state of *pyrites*, or metallic sulphurs and ores. Sometimes it exists in combination with calcareous matters in the state of earthy sulphur or liver of sulphur: fetid calcareous stones and swine-stone appear to be of this nature.

Recent discoveries extend the empire of this mineral still farther. It seems to be daily formed in animal and vegetable matters beginning to putrefy. Though these species of sulphur belong not properly to the mineral king-

kingdom; yet, to complete the natural history of this substance, we will subjoin them to the preceding varieties.

Varieties.

8. Sulphur in crystals, formed by the slow decomposition of an accumulation of animal-matters. Such is the sulphur found in the old lay-stalls, near the gate of St Anthony.
9. Pulverulent sulphur, formed by vapours arising from animal matters in the state of putrefaction; it is found on stable-walls, and in privies, &c.
10. Sulphur extracted from various vegetables, particularly from dock-root, from spirit of cochlearia, &c. For this discovery we are indebted to Messrs Baumé and Deyeux, members of the College of Pharmacy, and Lecturers in Chemistry, &c.
11. Sulphur obtained by M. Deyeux by an analysis of animal matters, particularly of the white of an egg.
12. Sulphur obtained from horse-dung. This combustible body has been found in horse-dung at the instant of its emission. Very probably future observation may discover it in many other animal matters.

But none of all these varieties of sulphur is that which is used in the arts. That sulphur is extracted by distillation from metallic compounds, of which it is a principle, and which are called *pyrites*. In Saxony and Bohemia, it is put into earthen tubes in small pieces,

pieces, and thus placed on an oblong furnace. One end of the tube stands in the furnace, and the other passes into a square vessel of cast-iron containing water. The sulphur accumulates in this receiver; but it is very impure. To purify it, it is melted in an iron ladle; the earthy and the metallic parts are then precipitated. It is next poured into a copper boiler, in which it is farther purified by depositing other extraneous matters. After being kept here in fusion for some time, it is poured into cylindrical wooden moulds, which give it the form in which we usually see it in commerce. The precipitate which subsides to the bottom of the boiler while it is in fusion, is grey and very impure. It is very improperly called *quick sulphur*. In other places, as at Rammerlsberg for instance, sulphur is extracted from pyrites by a simpler process. The sulphur of masses of pyrites roasted in the open air is taken off in ladles, and purified by a subsequent fusion.

Sulphur suffers no alteration from the contact of light. When heated in close vessels, it becomes soft and melts; and when afterwards cooled, it generally assumes a red, a brown, or a greenish colour, and a needle form. The process by which M. Rouelle crystallized it, was suffering the surface to congeal, and afterwards pouring off the fluid beneath: the under surface of the crust then exhibited the sulphur in needles crossing each other in various directions.

When melted sulphur is gently heated, it volatilizes in small pulverulent parcels of a citron yellow, which are called *flowers of sulphur*. This operation is employed successfully to purify sulphur, though it is the purest part which is volatilized. For performing this operation, common sulphur in powder is put into

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earthen cucurbite, which is fitted with earthen pots inserted one in another, and known by the name of *aludels*. The uppermost of these pots is terminated by a reversed funnel; the opening of which forms a slight communication between the interior part of the cucurbite and the air. The cucurbite is then heated till the sulphur become liquid; which at that degree of heat is sublimated, and fixed on the sides of the aludels.

Flowers of sulphur, when prepared in the great way, often contain a little sulphuric acid, which is formed by the combustion of a small quantity of the sulphur, in consequence of the vessel's containing a small portion of air. They may be entirely purified by washing them. The sulphur made use of in medicine, and in nice chemical experiments, should be prepared in this manner.

When sulphur is heated in such a way that air has access to it, it kindles and burns with a blue flame as soon as the heat causes it to melt, if the heat to which it is exposed be but inconsiderable; but when exposed to a strong heat, it gives a lively white flame. In the first of these instances it diffuses a suffocating smell; and by collecting the vapours which exhale from it, we obtain a portion of very strong sulphureous acid. When it burns rapidly it has no smell, and the residue is not sulphureous, but sulphuric acid. Stahl, who thought sulphur to be a compound of this acid with phlogiston, imagined, that when burnt it lost its inflammable principle, and was of consequence reduced to an acid. He has collected such a number of facts in support of his opinion, as could not but prevail with succeeding chemists to adopt it. But since chemists have begun to attend to the influence of air in combustion (a circumstance to which Stahl appears to have

paid scarce any attention), several of them, struck with the difficulty which has hitherto been found in all attempts to prove the existence of phlogiston, and with the facility with which all objections against that doctrine may be answered by means of the late discoveries concerning the nature of air, have adopted an opinion directly opposite to Stahl's concerning the nature and the combustion of sulphur.

The following are the facts on which this new opinion is founded. Hales observed, that sulphur absorbs a great quantity of air when it burns. M. Lavoisier has shown that sulphur is subject to the same laws with other combustible bodies: That is, 1. It cannot burn, except vital air have access to it. 2. During its combustion, it absorbs the purest part of that air. 3. That part of atmospheric air which remains after it has contributed to the combustion of sulphur, can no longer serve the same purpose. 4. The sulphuric acid produced by the combustion of sulphur is equal in weight not only to the quantity of sulphur, but also to the portion of air that has been consumed. 5. Consequently sulphur must combine with the base of pure air, or oxigene, in order to form sulphuric acid. That acid is therefore a compound of oxigene with sulphur; and the last of these is not a compound body, but one of the principles of the sulphuric acid. It forms the acid by combining with the base of vital air or oxigene; and this combination takes place when it is exposed to combustion. Heat is necessary to make it burn; for, by dividing it, and destroying its aggregation, it promotes its combination with oxigene. When once burnt, or combined with oxigene, it is no longer susceptible of inflammation, but becomes an incombustible body.

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It absorbs various quantities of oxigene, and becomes more or less acid, according to the manner in which it is burnt. Such is the theory of the difference between the slow and the rapid combustion of sulphur, and between the sulphureous and the sulphuric acids, which are produced by these combustions. Stahl thought, that when sulphur burnt slowly, it did not lose all its phlogiston; and that the sulphuric acid was odorous and volatile in consequence of its retaining part of it. It is now experimentally proved, that when sulphur burns slowly, it does not absorb the full quantity of oxigene, with which it is capable of uniting; but when it burns rapidly, it absorbs as much of that principle as is necessary for the formation of the sulphuric acid. The sulphureous acid, in combination with alkaline matters, passes into sulphuric acid by absorbing gradually the base of vital air from the atmosphere.

This theory serves equally to explain what happens when sulphur is formed by the combination of the sulphuric acid with certain combustible matters, as in the instances we have already mentioned, with sulphate of potash and of soda, ammoniacal, calcareous, magnesian, aluminous, and barytic sulphate, when heated with coal. The combustible body seizes the oxigene contained in the sulphuric acid, and leaves only the sulphur, which is its other principle. Whenever, therefore, the sulphuric acid is converted into sulphur by a combustible body, the latter is constantly reduced to the state of a burnt body, as we shall have occasion to see in the history of several of the metals. On this account a large quantity of carbonic acid is obtained, when sulphur is artificially produced, as the oxigene of the sulphuric acid is united with the pure carbonaceous

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matter. The reader may recollect, that the existence of oxigene, or the base of pure air in the sulphuric acid, is easily demonstrable. Various attempts have been made to determine by experiment the proportions in which oxigene and sulphur are combined in the sulphuric acid, in the same manner as the proportion of the nitric, the carbonic, and the phosphoric acids have been determined.

Sulphur is neither liable to any alteration from air nor soluble in water. If, after being kept in fusion till it become thick, it be poured into water, it then becomes red, and retains a certain degree of softness, so that it may be kneaded in the hand; but in a few days it loses these properties. Water dropped on sulphur does not seem to be decomposed, nor contribute to the combustion of the sulphur; from which it appears, that the base of vital air or oxigene has a greater affinity with hydrogene than with sulphur. This assertion is confirmed by the manner in which hydrogenous gas acts on the sulphuric acid, for it robs it of its oxigene.

Sulphur does not act at all on siliceous earth; it combines with aluminous earth, but not without great difficulty. This earth, however, when it is very much attenuated, appears to reduce it to the state of an hepatic or fetid sulphure, as may be observed in the preparation of pyrophorus.

A compound of sulphur with alkaline matters is generally called *alkaline sulphure*, *hepar*, or *liver of sulphur*. This compound is generally of a lighter or deeper brown colour, like the liver of animals: vital air decomposes it; water dissolves it, causing it to give out a fetid smell; the acids precipitate the sulphur, extricating from it a peculiar gas, which was at first named *hepatic gas*; but to which, in allusion to its nature

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ture, we now give the name of *sulphurated hydrogenous gas*. There are six species of alkaline sulphures produced by barytes, magnesia, lime, the two fixed alkalis, and ammoniac or volatile alkali. We may examine the properties of each of these by itself.

Pure barytes does not act strongly on sulphur, when they are heated together in water; the product is a weak sulphurated or hepatic liquor: but in the dry way, the two bodies enter into a much more intimate combination. Therefore, when a mixture, consisting of eight parts of barytic sulphate in powder with one part of coal, is exposed in a crucible to a strong heat, an incoherent mass is obtained without fusion, which readily dissolves in warm water, and has the smell and all the other characteristics of an hepar. The solution is of an orange or golden yellow colour. I have discovered that it crystallizes by cooling. Barytic sulphur in crystals is of a yellowish white colour: when exposed to the air, it attracts moisture from it, assumes a deeper colour, and is decomposed; for the sulphur is precipitated, and barytic sulphate formed. This sulphur, when precipitated by acids, gives out an elastic fluid, known by the name of *sulphurated hydrogenous gas*, which has been mentioned above, and the peculiar properties of which we will afterwards examine. When barytic sulphate is precipitated by the sulphuric acid, the precipitate is found to consist of both sulphur and barytic sulphate; but when the nitric, or the muriatic acid is employed, the barytic nitrate, or muriate remains in solution, and only the sulphur subsides.

Sulphur combines with pure magnesia with the help of heat. The neutral salt, which we call *carbonate of magnesia*, is commonly used for this combination, as

dissolving most readily in water. A small portion of magnesian carbonate, with an equal quantity of flowers of sulphur, is put into a bottle full of distilled water. This vessel, entirely emptied of air, and closely stopped, is exposed for several hours to the heat of a balneum-mariæ; the water is then filtered; it has the fetid smell of rotten eggs; it communicates an high colour to solutions of metals; it gives by spontaneous evaporation small crystalline needles; in a word, it is a genuine magnesian sulphure. The magnesia may be precipitated by one of the fixed alkalis,—which have a greater affinity than it with sulphur. The acids separate the sulphur in the form of a white powder; from which its existence in this mixture is certainly known. Such was the liver of sulphur which M. le Roi, physician at Montpellier dissolved in pure water, in order to form an imitation of sulphureous mineral waters. But it is now known, that scarce any of these waters contains genuine sulphure; they are mineralized by sulphurated hydrogenous gas.

Lime unites with sulphur with much more rapidity and eagerness than either of the salino-terreous substances. When a little water is poured on a mixture of quicklime with sulphur in powder, the heat disengaged by the action of the water on the lime occasions a combination between the lime and the sulphur. If more water be added, the mixture assumes a reddish colour, and exhales a fetid odour. It retains in solution the sulphur in combination with the lime. It is difficult to prepare this calcareous sulphure in any other way but the humid. When the lime is not very quick and does not produce much heat on coming into contact with water, it is often found necessary to assist the combination by a moderate fire. This compound is

a lighter or a deeper red, according to the causticity of the lime. I have observed, that when the solution is much concentrated, it deposites, by cooling, a layer of small needle crystals, of an orange yellow, arranged in tufts, which to me appeared to be compressed tetrahædral prisms, terminating in dihædral summits. In the air these crystals gradually lose their colour, and become white and opaque, without suffering any alteration of form. Calcareous sulphure, moistened with a little water, and distilled in a pneumat-chemical machine, is decomposed in part, and affords a large proportion of sulphurated hydrogenous gas. If evaporated to dryness, and calcined in a crucible till it ceases to fume, what remains after the operation is calcareous sulphate formed by lime and the sulphuric acid produced by the slow combustion of the sulphur. Calcareous sulphure is very soon altered by air; as its gas flies off it loses its smell and colour. When dissolved in a large quantity of water, it suffers the same alteration; especially if it be shaken, as M Monnet has observed in his Treatise on Mineral Waters: what remains after these alterations is calcareous sulphate. If preserved in bottles, partly empty, it deposites a blackish crust on the sides of the bottles, and crusts or pellicles are from time to time formed, which sink to the bottom of the liquor. If the vessel containing it be closely stopped, it remains long unaltered, as I have often observed in my own laboratory. I know of some of this preparation which was made up 15 years ago, and which still retains its colour and smell, and affords a copious precipitate when acids are applied to it. Calcareous sulphure is decomposed by the pure fixed alkalis, which have a greater affinity with sulphur than sulphur has with lime. Acids precipitate the sulphur in the form of a very fine white

powder, which has received the name of *magister of sulphur*. The carbonic acid effects this precipitation, as well as the rest of the acids. The manner in which neutral salts act on calcareous sulphure is unknown.

The two fixed alkalis, in a pure or caustic state, act in a very remarkable manner on sulphur. They form with it those sulphures which are most permanent and least liable to decomposition. I have discovered that the fixed alkalis when dry and very caustic, act upon sulphur even cold. All that is requisite to promote this phenomenon is to triturate solid potash or soda in a mortar with powdered sulphur. The mixture becomes soft, assumes a yellow colour, exhales a fetid odour, and forms a sulphure. But when it is dissolved in water, the solution is only of a pale yellow colour, and does not contain so great a quantity of sulphur as the same sulphure prepared with heat. Alkaline sulphure is prepared in two ways in the laboratory,—the dry, and the humid way. The following are the particulars of the first process: Equal parts of pure and solid potash or soda and powdered sulphur are put into a crucible; heat is then applied till the mixture be entirely heated: when in fusion, it is poured on a plain marble surface; and when cooled, it displays a deep red colour, like the liver of an animal. M. Gengembre, who has read before the academy an account of some very valuable experiments on sulphurated hydrogenous gas, has made an important observation on alkaline sulphure prepared in the dry way. It is, that this compound is not at all fetid, and exhales no sulphurated hydrogenous gas while it continues dry. Till it be dissolved in water, or attract moisture from the atmosphere, it never gives out any smell; from which

circumstance it appears, that the disengagement of the fetid gas is effected by water, as we shall afterwards more particularly explain. The two fixed alkalis, when pure and caustic, act precisely in the same manner on sulphur, dissolving it likewise in the dry way. These combinations of the caustic alkalis with sulphur have as yet been but very little examined; alkaline sulphure has been almost always composed with fixed alkali, saturated with the carbonic acid. There are, however, considerable differences between these two sulphures. First, those which are made up with effervescent fixed alkali require more time to be taken up in the preparation; for fixed alkali is less active in this state than when pure. But the most important difference which we have had occasion to observe, as subsisting between sulphures made up with caustic fixed alkali and those made up with effervescent fixed alkali in the dry way, is the comparative state of their saturation. The former are more fetid, and browner, when dissolved, and the gas which they afford is much more inflammable than that given out by the others. The latter are of a paler colour, which is often a greenish grey; their smell is fainter, and their composition less lasting. It appears that the fixed alkalis retain a portion of carbonic acid when in union with sulphur; for the gas of these sulphures, in which sulphur is united with alkaline carbonate, is not inflammable till after being washed in lime-water, which carries off the acid. In the presence of this acid therefore, and in its power of enfeebling the caustic qualities of alkali, we find the cause of those appearances which distinguish caustic sulphures from such as are not caustic.

Solid alkaline sulphure, composed with either of the caustic fixed alkalis, is extremely fusible: air decomposes

poses it like calcareous sulphure. When heated in close vessels, after being moistened with a little water, it affords a large proportion of sulphurated hydrogenous gas. After being melted, it may be crystallized by cooling; but its crystallized form has not yet been well described. While hot and dry, it is of a brown colour; in proportion as it cools, and attracts moisture from the air, it loses that colour, and becomes paler; in a short time air causes it to assume a greenish yellow colour; it is again dissolved into a liquid, and becomes, after some time, sulphate of potash or of soda. It dissolves easily in water; and immediately begins to exhale a peculiar fetid odour. The odorous gas, which before had no existence, is now formed by the re-action of the water. This solution has a deep red, or a green colour, according as the alkaline sulphur is newly prepared or old. Alkaline liver of sulphur or sulphure prepared in the humid way, by heating in a matraass caustic fixed alkali dissolved in water, with a quantity of sulphur in powder equal to half its weight, exhibits the same properties as this solution; and we may give the history of both at once under the common name of *liquid alkaline sulphure*.

Liquid alkaline sulphure, when highly concentrated, deposites by cooling irregular needles. It is liable to decomposition by the action of heat; when distilled in a pneumat-chemical machine, it gives sulphurated hydrogenous gas. Air likewise decomposes it; and it is then covered with pellicles, and deposites sulphur, and becomes turbid. Bergman and Scheele have proved this decomposition to be owing to the vital air diffused through the atmosphere. In fact, when a little liquid alkaline sulphur is put into a bell-glass containing vital air, the oxigene is entirely absorbed, and the vital air de-

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decomposed. Scheele has even proposed this as an eudiometer ; and it is now acknowledged to be one of the best.

Neither the earths nor the salino-terreous substances act upon liquid alkaline sulphure when it is very pure : but when it has been prepared with carbonate of potash or soda, lime-water renders it turbid. The acids decompose it, by combining with the alkali, and precipitate the sulphur in the form of a fine white powder. The nitric acid, according to M. Proust, produces a detonation, when it is poured on solid alkaline sulphure. When any large quantity of the oxigenated muriatic acid is poured on a solution of alkaline sulphure, it does not produce any precipitate, or at least but a very trifling one ; because it dissolves the sulphur again, in consequence of its oxigene being nearly free, and uniting so rapidly with that combustible body so as to convert it into sulphuric acid. The certainty of this fact may be farther proved by pouring a portion of barytic muriate into the mixture ; a copious precipitate of barytic sulphate is then produced. All the acids, when they decompose this sulphure, cause it to give out a gas, which may be collected into a pneumatocchemical machine, and is worthy of a particular examination.

In order to obtain this gas, an acid must be poured on alkaline sulphure in powder : a lively effervescence is then produced, which would not take place in the same manner if the acid were poured into a solution of the alkaline sulphure. This phænomenon, which has not yet sufficiently engaged the attention of chemists, depends upon two circumstances. 1. Solid alkaline sulphure does not contain hepatic gas or sulphurated hydrogen ready formed, as has been observed by M. Gen-

Gengembre ; and when an acid is poured upon it, the water which holds the acid in solution contributes to the formation of hepatic gas. As a large quantity of this gas is instantly produced, finding no body to retain it in solution, it flies off, occasioning at the same time a considerable effervescence ; so that if the experiment be made in a tubulated flask, with its tube inserted into a bell-glass filled with water, the elastic fluid may be easily collected. 2. The solution of alkaline sulphure contains a good deal of gas ready formed ; but part of it has been already disengaged, when the sulphur was dissolved ; and when an acid is added, the portion of gas which it disengages is gradually dissolved in the water ; so that it produces no sensible effervescence, or at least a very inconsiderable effervescence, and no great quantity of gas can be collected.

Sulphurated hydrogenous gas, which is the same in all earthy or alkaline sulphures, and is always an evidence of their existence, has been long known by its fetid smell and its action on metals and metallic oxides, especially those of lead and bismuth, which it very soon blackens. Its fœtor is quite insufferable ; it is instantly fatal to animals ; it communicates a green colour to syrup of violets, and burns with a light blue flame. If set on fire in a large bell-glass, very suitable for the purpose, it clouds the sides of the vessel, as it burns, with a depofite, which is certainly sulphur. Vital air decomposes this gas ; whenever it comes into contact with atmospheric air, there is a portion of sulphur separated from it. For this reason, the sulphureous waters, mineralized by it, do not contain genuine alkaline sulphur ; though sulphur be seen swimming on their surfaces, and found deposited in the arches or basons in

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which it is contained : the waters of Aix-la-Chapelle, Enghein, &c. afford instances of this. The sulphureous deposites which may be observed in flasks containing solutions of alkaline sulphur, are likewise owing to this decomposition of sulphurated hydrogenous gas by vital air. Bergman attributes this instance of decomposition to the strong affinity between pure air and phlogiston. Hepatic gas he considers as a combination of sulphur, phlogiston, and the matter of heat. When one of these principles is separated, the other two can no longer remain in union. M. Gengembre, struck with this phænomenon, that sulphurs neither contain nor exhale sulphurated hydrogenous gas, except when dissolved in water, or made up in the humid way, thinks, that the fluid may possibly contribute to its formation by undergoing a decomposition,—that while its vital air unites with one part of the sulphur, its hydrogen, which is at the same time disengaged, dissolves likewise a small portion,—and that this solution constitutes sulphurated hydrogenous gas. He imitated the formation of this gas by melting sulphur above mercury, under a bell-glass filled with hydrogenous gas, by the action of the rays of the sun collected in a lens nine inches in diameter. The sulphur was partly dissolved, and communicated to the gas all the characteristic properties of hepatic gas. But as sulphur by itself does not decompose water, and as oxygen has a greater affinity with hydrogen than with sulphur, M. Gengembre thinks, that alkali promotes the decomposition of water by sulphur, in consequence of its tendency to unite with the body produced by the combination of sulphur with oxygen; that is, with the sulphuric acid. In support of this theory, M. Gengembre observes, that the more powerful acids have to retain their oxygen,

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so much the more sulphurated hydrogenous gas do they disengage from alkaline sulphures, because the water is then decomposed rather than the acid. Such, in his opinion, is the reason why the muriatic acid affords one half more of this gas than the nitric acid; as has been remarked by Messrs Scheele and Sennebier. Lastly, Scheele's process for obtaining a considerable quantity of sulphurated hydrogenous gas, by dissolving, in a dilution of the sulphuric acid in water, an artificial pyrites, consisting of three parts of iron and one of sulphur, strongly confirms this opinion. It appears then, that vital air decomposes sulphurated hydrogenous gas by combining with the hydrogen to form water, while the sulphur is precipitated.

Water dissolves sulphurated hydrogenous gas readily enough; and the solution is a perfect imitation of mineral waters.

The earths and the alkaline substances seem to have no power of action on this gas.

The sulphuric acid does not decompose this gas; but the sulphureous acid robs it of its sulphur, because the oxygen of this gas being partly in a free state, unites more readily with the hydrogen of the gas.

The red nitrous acid in which the oxygen is but very feebly retained, acts with great strength in decomposing this gas, and precipitates the sulphur. This acid is very happily employed to determine whether sulphur exists in mineral waters.

Alkaline sulphure decomposes earthy neutral salts as well as solutions of metals; as we shall hereafter see.

Liquid ammoniac has scarce any power of acting on concrete sulphur. Yet Boerhaave asserts, that, when that liquor stands long over flowers of sulphur, it tinged

ges them with a golden colour, To make these two bodies enter into combination, one of them must be in the state of vapour when they are brought into contact. For this purpose, a mixture, consisting of equal parts of quick-lime and ammoniacal muriate, and half a part of sulphur, is submitted to distillation. In this process, which must be carefully conducted, a reddish yellow liquor is obtained, of a pungent and fetid alkaline smell; in a word, a genuine ammoniacal sulphur, which exhales a whitish smoke when brought into contact with air, from which property it has received the name of *Boyle's fuming liquor*. Heat decomposes this ammoniacal sulphure: in a certain space of time, a great many small *irised* needles, a line or two in length, are formed in it: they appear to be concrete ammoniacal sulphure in crystals. A thin, blackish, and often golden crust is formed on the sides of the vessels. Lime and fixed alkali decompose the fuming liquor; the acids, too precipitate the sulphur with great facility, and disengage sulphurated hydrogenous gas in an highly inflammable state. From these decompositions there result different ammoniacal salts, according to the nature of the acid employed. A mistake which I made in one of my courses, led me to observe a fact which deserves to be laid before the reader. Wishing to precipitate Boyle's fuming liquor, I took up a flask standing on my table, and inscribed *spirit of vitriol*: it was almost empty, which hindered me from observing that what it contained was sulphuric acid highly concentrated. I poured a few drops of it on ammoniacal sulphure; a rapid motion was instantly excited, a very thick white cloud arose out of the vessel containing the mixture, and it produced a report like that of a large gun; the liquor springing out of the glass, was carried to a considerable

siderable distance; the glass became very hot, and burst into pieces; on some of its fragments there remained a little sulphur in a thick yellowish magma. I repeated this experiment many times with proper precautions, and still found it attended with the same result; a violent motion was produced, and the mixture was carried to a distance. But these several phenomena succeed each other so rapidly, that it is impossible to avoid confounding them. I have not found the most fuming nitrous acid to produce the same effects on ammoniacal sulphure that had been prepared some time before. The mixture was violently agitated; a considerable degree of heat and ebullition was produced, a white cloud of ammoniacal nitrate issued from the vessel; but there was no explosion, such as the concentrated sulphuric acid produces on the same hepatic liquor, however long it may have been prepared. M Proust affirms, that when nitrous acid is poured on two drams of Boyle's fuming liquor, it produces as violent a shock as two grains of fulminating powder could produce. But this phenomenon does not take place unless the ammoniacal sulphure have been recently prepared.

Ammoniacal carbonate likewise combines with sulphur. When these two bodies, both in a vaporous state, come into contact, they combine to form a concrete ammoniacal sulphure. It is obtained by distilling a mixture consisting of equal parts of carbonate of potash or lime and ammoniacal muriate, together with half a part of sulphur. This sulphure is of a brown colour, and in crystals; when dissolved, it exhales some white vapour: heat decomposes it; air alters it and destroys its colour. It is liable to decomposition by acids, &c. The sulphurated hydrogeneous gas

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which it affords, contains carbonic acid. It is to be observed, that this concrete ammoniacal sulphure is nothing but ammoniacal carbonate, contaminated with a little of Boyle's liquor; for it is impossible for ammoniac to hold sulphur in solution when combined with the carbonic acid, as this acid readily precipitates the sulphur of ammoniacal sulphure.

Several of the acids have a stronger or a weaker power of action on sulphur. If sulphuric acid be boiled on sulphur, the acid acquires an amber colour, and a sulphureous smell; the sulphur melts and swims like oil: when cooled, it is formed into concrete globules of a lighter or a deeper green, according as the sulphur has been for a longer or a shorter time in solution. A small portion of the sulphur remains dissolved in the acid, but may be precipitated, as M. Baumé has shown, by means of alkali. This experiment, and several others of the same nature, have led M. Berthollet to think that the sulphureous is nothing but the sulphuric acid, holding sulphur in solution. And his opinion actually agrees with all the modern experiments which have any relation to this matter; for they concur in showing, that the sulphureous differs from the sulphuric acid only by containing a greater proportion of sulphur.

The flaming red nitrous acid acts powerfully on sulphur. M. Proust first observed, that when red nitrous acid is poured on melted sulphur, it occasions detonation and inflammation. M. Chaptal has made a series of experiments on this matter. By distilling nitrous acid on sulphur, he dissolved it so as to produce sulphuric acid: and it appears therefore, that oxygen has a greater affinity with sulphur than with azote or radical nitre.

The common muriatic acid effects no alteration on

this combustible body; but the oxygenated muriatic acid acts upon it with more energy. But our experimental knowledge of this fact is so imperfect that it is unnecessary for us to insist longer upon it here.

Sulphuric neutral salts are incapable of acting on sulphur; but nitric salts cause it to burn rapidly, even in close vessels. The theory of this important phenomenon is very simple. Nitre decomposed by heat affords a very considerable quantity of vital air: sulphur is a very combustible substance, or, which is the same thing, has a strong tendency to combine with oxygen; nitre affords the principle necessary to its combustion; so that the atmospheric air is no longer requisite to make it flame. The products obtained by this operation are very different, according as the nitre and the sulphur are employed in different proportions. If a mixture consisting of eight parts of sulphur and one of nitre be set on fire in a close vessel, the sulphur burns with a very lively white flame, and is converted into sulphuric acid. This method has been used for the last twenty years in England and Holland for preparing this acid, which was formerly obtained from *vitriol*. In England, large glass balloons, with very large necks holding each four or five hundred pints, were the vessels first used in making this preparation. A number of these were arranged together on a bed of sand; they were disposed in two lines at a proper distance from each other, so that a person might conveniently go and come between them: a few pounds of water were put in each of the vessels, and a stone pot was introduced into the neck of each, having upon it a red-hot ladle of cast iron with a long handle. Into this ladle, by means of another ladle of white iron, there was put a mixture of sulphur and nitre in due proportions: after

which

which the aperture of the balloon was stopped with a piece of wood. The heat of the ladle kindled the mixture; the sulphur was burnt with the vital air of the nitre; and after the combustion was effected, the ladle was taken out, and the vapours suffered to condense. The same operation was repeated on all the balloons of the two rows; so that when the operator returned to the first balloon, he found the vapours entirely condensed, and might proceed to burn in it a new quantity of the mixture. When the water was sufficiently saturated with the acid, it was poured out into glass retorts: the water was then separated by distillation, and the acid concentrated, till a phial containing an ounce of distilled water would receive a quantity of it weighing one ounce seven drams and an half. Such was the English process for preparing *oil of vitriol*, or concentrated sulphuric acid. But it was attended with great expence, on account of the high price and the brittleness of the balloons. A few years ago, there was a method contrived of burning sulphur in a sort of gridirons in large apartments lined all over with lead; the sulphuric acid, as it condensed, is conveyed by gutters into a reservoir, and afterwards concentrated by the action of fire. This is the process used in the manufactory of Javelle near Paris; the establishment of which cannot but be of advantage to the arts. It is of consequence to observe, that the sulphuric acid thus obtained is always in union with a little sulphur and sulphate of potash; it is likewise found to contain a little aluminous sulphate and some sulphate of lead. But these substances are mixed with in so inconsiderable a proportion, that their effects are of no consequence in most of the occasions on which the saline matter is employed: besides, it may be easily

ly purified, by distilling it to dryness, so as to be suitable enough even for the nicest chemical experiments.

If instead of an eighth part of nitre, we burn equal parts of sulphur and of nitre; then, instead of sulphuric acid in a free state, the product obtained is sulphate of potash, formed by the combination of that acid with the fixed alkaline base of nitre. Salt obtained in this manner was called *Glafer's polychrest salt*. It was prepared by casting into a red-hot crucible, a mixture consisting of equal parts of sulphur and nitre. The residue was dissolved in water, and the solution evaporated to a pellicle; it was then filtered, and afforded by cooling crystals of genuine sulphate of potash; which received their particular denomination, because Glafer was the first who made known this mode of preparation: but the salt thus obtained differs in no respect from common sulphate of potash.

Gun-powder, the terrible effects of which are owing to its strong tendency to combustion, is a mixture of sulphur and nitre with charcoal. Most part of it is nitre; the proportion of charcoal is much less; and it contains but a very trifling quantity of sulphur. A hundred pounds of gun-powder from Effone near Colbeil, contain seventy-five pounds of nitre, nine and an half of sulphur, and fifteen of charcoal. The mixture is triturated for ten or twelve hours in wooden mortars, with pestles of the same substance; a very small portion of water is from time to time poured upon it. When the fluid is almost wholly evaporated by the trituration, so that the powder may be put on a stone-plate without wetting it, it is then taken away to be granulated. The granulation of powder is accomplished by passing it thro' several sieves, which are moved backwards and forwards in

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straight line. The holes of those sieves are of various sizes, the smallest being those which form grains of gun-powder. The granulated powder is next sifted to separate the dust: it is then carried to the house for drying it; which is a shed exposed to the south, and receiving the rays of the sun through glass windows. Cannon-powder receives no farther preparation. Musket-powder is glazed, that it may not soil the hands. To perform this operation, a cask with a square axis passing through it, which communicates with a water wheel, is half filled with powder. The motion of the wheel occasions a continued friction, by which the grains of the powder are worn smooth. The powder thus glazed, is passed through a sieve to separate the dust; and afterwards through another sieve, which divides the grains into two kinds of musket-powder, a finer and coarser. M. Baumé, in conjunction with the Chevalier d'Arcy, has made a series of laborious experiments on the preparation of powder, on the different degrees of the force of this compound substance, according as its ingredients are mixed in different proportions, and on its analysis. In the course of these, the gentlemen have made a variety of discoveries, of which we shall here mention only the most important, and such as have a more immediate connection with the theory of chemistry. 1. No good powder can be made without sulphur, though this mode of preparing it has been attempted by several people: sulphur increases its strength amazingly. 2. All coals, whether light or ponderous, except such as are formed by the combustion of animal matters, are equally proper for this composition. 3. Coal is one of the most essential parts of powder; for a mixture of sulphur and nitre is far from producing the same effects as when coal is added.

4. The goodness of powder depends entirely on the substances of which it is composed being duly proportioned, and the trituration being continued till the matter rise in dust all around the mortar. 5. The effects of powder are much more powerful when it is simply dried than when it is granulated. The moisture necessary to make powder assume a granulated form crystallizes the nitre, which is then separated from the other substances; and it may be perceived in the interior part of the grains, if they be cut asunder, and examined through a magnifier. 6. Glazed or musket-powder has less strength than cannon-powder, which has not undergone the same operation; because the particles of the former are more closely united, and of consequence not so inflammable.

As to the analysis of powder, M. Baumé effected that in a very simple way. His process consists in washing cannon-powder, after it has been sufficiently pulverized, with distilled water, and evaporating the water; by this first operation the nitre is obtained; the residue is the charcoal and the sulphur. The sulphur seems to be in part fixed by the coal, so that it cannot be entirely separated by sublimation. M. Baumé employed a faint heat, capable of burning sulphur but not charcoal. The charcoal, however, always retains a little sulphur; for as that chemist has observed, it exhales a sulphureous smell till it be entirely reduced to ashes. He estimates the sulphur retained by the charcoal at one twenty-fourth part of the total weight. The powder may likewise be dissolved, by exposing it entire and unwaſhen to the action of a moderate fire. This fact was known to Mr Robins, who gives an account in his *Treatise on Gunnery*, written in English. Poachers are said to be in the practice of depriving powder

powder of its sulphur by heating it on warm ashes in a tin plate. They are persuaded from experience, that powder thus deprived of its sulphur, expels the shot to a farther distance, and is least injurious to the fire-arms.

Chemists and natural philosophers have entertained various opinions concerning the violent effects of gunpowder. Some have attributed them to the reduction of the water to vapour; others to the sudden dilatation of the air. M. Baumé thinks that they are owing to the formation of nitrous sulphur at the moment of combustion. In my opinion this phænomenon may be very easily explained, with the help of the modern discoveries. In order to understand my theory, the reader must first take notice, that whatever passes during the inflammation of powder is owing to its extreme combustibility. But both sulphur and charcoal, when they have undergone a considerable comminution, are very inflammable bodies. The intimate mixture which has such an influence on the strength of powder, according to the valuable experiments of M. Baumé, is the sole cause of the effects which it produces. The nitre is equally distributed through all the integrant parts of these extremely combustible bodies. As the quantity of the nitre is much more considerable than that of either of them, each particle of the sulphur and the charcoal is inclosed, and as it were incruited in nitre. Each of the two combustible bodies has of consequence much more vital air than is requisite to make it burn completely; for it has been shown that nitre, when acted upon by heat, gives out a considerable quantity of that fluid. The same thing happens therefore in this case as when a combustible body is immersed into a vessel filled with vital

air. On such an occasion it is known, that the body scintillates while it burns, and is much sooner consumed than it would have been in atmospheric air. From this we can easily conceive the cause of the rapid inflammation of gun-powder; why it takes place in close vessels as well as in the open air; and why, when any obstacle is opposed to so terrible an agent, it produces such explosions, and expels the obstacle with such violence.

The effects of this mixture of nitre, sulphur, and charcoal, are nothing in comparison with those produced by another mixture called *fulminating powder*. That powder is made up of three ounces of nitre, two of carbonate of potash, or *fixed salt of tartar*, very dry, and one of powdered sulphur. This mixture is triturated in a hot marble mortar with a wooden pestle, till the three matters be fully mixed. A dram of this powder exposed to a moderate heat in an iron ladle, melts, and in a short time produces a detonation as loud as the report of a cannon. To understand the cause of this phenomenon, which is the more astonishing, because fulminating powder does not need to be inclosed and pressed together like gun-powder, in order that it may produce it, we must observe, 1. That it does not take place, except when the mixture is slowly heated, till it become liquid. 2. That when fulminating powder is cast on burning coals, it only melts like nitre, without noise. 3. That a mixture of sulphure of potash with nitre, in the proportion of one part of the first substance to two of the second, fulminates more rapidly, and with as much noise as that which is made up of sulphur, nitre, and alkali. It appears therefore, that when fulminating powder is heated, it produces sulphure of potash before detonizing. This

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fact alone explains the phenomenon which we are considering. When nitre in crystals and sulphure of potash are exposed to the action of heat, sulphurated hydrogenous gas is disengaged from the sulphure, and vital air from the salt. These two gases, which, as we have seen in the history of hydrogenous gas, are capable of producing a smart detonation, are inflamed by a part of the sulphur which kindles of itself. But as the thick fluid through which they must pass opposes an obstacle to their inflammation, and as they kindle on all sides at once, they strike the air with such rapidity in their combustion, that it resists them in the same manner as the sides of fire-arms resist gun-powder. This resistance appears evidently from the effects which fulminating powder produces on the ladle in which it is exposed to the fire; the bottom of that vessel is pierced through, or bulged outwards, and its sides are bent inwards, as if it had been exposed to the action of a force directed perpendicularly downwards, and another acting laterally.

The last mixture of nitre and sulphur which we have to consider is called *powder of fusion*. It is made up of three parts of nitre, one of sulphur, and one of saw-dust. A little of this powder is put into a nut-shell, with a bit of copper rolled together; fire is then set to it; it kindles and burns with rapidity, melting the piece of copper, which is afterwards found in that state at the bottom of the shell; though the shell is only weakened, not burnt. But it is necessary to immerse it in water as soon as the powder ceases burning. This experiment proves the powder employed in it to be a very fusible matter. But as it is mostly owing to the action of the sulphur on the metal, we will take more

more particular notice of it in the history of metallic matters.

The muriatic, the fluoric, and the boracic neutral salts, have no power of action on sulphur. We have seen, that the alkaline carbonates unite with this substance, and render it soluble in water, by forming alkaline sulphures which are not caustic.

Hydrogenous gas does not act in a determinate manner on sulphur. Formerly, it was quite natural to find a strong analogy between these two bodies; for when sulphuric acid diluted in water is combined with combustible matters, it produces hydrogenous gas; and if it be concentrated, it affords sulphur. Sulphur is likewise formed in large masses of putrefying animal matters. When combined with alkaline matters, sulphur appears to suffer an alteration of nature, passing into the state of sulphurated or *hepatic* hydrogenous gas. Lastly, Hydrogenous gas acts on a great many bodies, nearly in the same way as sulphur. We might still think, therefore, that these two bodies were in some measure the same, were it not fully demonstrated, that hydrogenous gas is almost always produced by the decomposition of water, and equally certain that sulphur is never a principle of that substance.

Sulphur is capable of combining with many other substances; but as we are still unacquainted with those substances, we will defer giving an account of their union with this mineral, till we come to describe their properties.

Sulphur is an excellent medicine for pituitous diseases of the lungs, and still more so for cutaneous disorders. It is successfully administered in the case of the humid asthma, and in scorbutic eruptions, &c. It is given either in flowers or in lozenges made up with su-

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gar. It is mixed with fats into an ointment for rubbing such parts of the body as are affected with the itch. Alkaline sulphures have been proposed as remedies for obstructions, numbness, palsies, cutaneous disorders, &c. Some physicians have supposed, that sulphur is not dissolved in animal humours; yet it is certain that it penetrates to the extremities of the most minute vessels; for the breath, the urine, and the saliva of persons, who make use of sulphur are impregnated with it. Sulphurated hydrogenous gas dissolved in mineral waters, as in those of Cauterets, Aix-la-Chapelle, Barege, Enghien, &c. communicates to them incisive qualities, which render them very serviceable in disorders of the skin, lungs, and joints, and in palsies, &c.

Sulphur is no less useful in the arts. It is one of the most necessary ingredients of gun-powder. It is used in taking the finest impressions of engravings on stone; it is made into combustible matches; it is burnt to whiten silks, to destroy certain colours, and to put a stop to the fermentation of wines, &c. It has been proposed for fixing iron in stones, &c.

C H A P.

CHAPTER IV.

Genus IV. *Metallic Substances in general.*

METALLIC substances are a very important and useful order of natural bodies, in their application to the purposes of common life, in chemistry, and in medicine. They are essentially different from saline and earthy matters, both in their physical characteristics and in their chemical properties.

Before entering upon a particular examination of each of these substances, it will be proper to consider them in general. In doing this, we will treat, 1. Of their physical properties. 2. Of their natural history. 3. Of the art of assaying them, or determining their nature and quantity. 4. Of metallurgy, or the art of working them in the great way. 5. Of their chemical properties. 6. Of the means of distinguishing them from one another, and of the distinctions necessary to be made among them.

§ I. *Of the Physical Properties of Metallic Substances.*

METALLIC substances are absolutely opaque; much more so than stones; for a very thin plate, even of the most opaque stone, is in some degree transparent; whereas the thinnest plate that can be formed of any metal is equally opaque with the largest mass. The opacity of metallic substances renders them peculiarly suitable for reflecting the rays of light: no body possesses this property in so eminent a degree as they; glass mirrors must be coated with metal in order that they may reflect objects. This property peculiar to metals is the cause of their lustre or brilliancy; a quality which is always in the compound ratio of the density or hardness of any metal which enables it to receive a fine polish, and of its colour. White metallic substances reflect more rays, and are more brilliant than those which are coloured.

The specific gravity of metallic substances is much more considerable than that of other mineral bodies. A cubic foot of marble weighs but two hundred and fifty-two pounds; a cubic foot of tin, which is the lightest of all metals, weighs five hundred and sixteen pounds. This superior gravity of metals, which so much exceeds that of earthy matters, depends no doubt on their extraordinary density, to which they owe likewise their lustre and opacity.

Most metallic substances may be dilated by repeated percussion, or by strong pressure. This property, which

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is peculiar to these substances, and of which we have not before had occasion to take notice in any of the matters which we have hitherto been examining, bears the name of *Ductility*. It may be distinguished into two kinds: the one, ductility under the hammer, or *malleability*, makes those metals to which it belongs to admit of being beaten out into thin plates without breaking: lead and tin are metals possessing this kind of ductility. The other is the continued and almost extreme prolongation of metallic matters, so as to form them into threads of more or less fineness: this is the ductility of wire, of which iron, copper, and gold are susceptible. It is likewise called *tenacity*. It is of the more consequence to distinguish accurately between these two species of ductility, because they appear to be really very different from each other; for metallic substances which are very malleable often have scarce any tenacity; while others, which have much of the ductility of wire, are scarcely malleable. The tenacity of metals may be very accurately expressed by mentioning the weight which a wire of any metal of a known diameter is capable of sustaining without breaking. Both of these properties seem to depend on the particular form of the integrant parts of the various metals to which they belong. Metals which admit of being beat out into thin plates, seem to consist of small laminæ, which, when compressed, are removed from a vertical to a lateral direction in regard to each other, so that the superficies of the mass is increased while its thickness is diminished. Those again which are susceptible of being spun into wire, seem to have a fibrous contexture: their fibres being disposed in collateral bundles, unite and eke out one another, when exposed to that violent pressure which forms them into wire.

But the ductility of metals goes only a certain length. When any metal, however ductile, has been repeatedly beaten with an hammer, it becomes hard and brittle, and its length can be no farther extended. This property is named *induration*. When an indurated metal is slowly heated with proper precautions, it regains its ductility, and may be again struck with the hammer without danger of breaking. It appears that the parts of any metal are lengthened out under the hammer only in proportion as they find space, which they may occupy when they flee the pressure to which they are exposed. And it may be easily understood, that when those parts have been once so closely compressed by percussion that scarce any interstices remain between them, they can no longer escape from under the hammer, and the metal must therefore break into pieces. Heat, by dilating the metal, again separates its parts, and produces new spaces between them, which afford them room to unite more closely in consequence of repeated percussion.

As some metallic substances are not at all ductile, chemists and naturalists have distinguished them into classes, according as they possess or want this property. They give the name of *metals* to those substances in which the properties of ductility, opacity, gravity, and metallic brilliancy are united; and they call those *semi-metals*, which, though apparently metallic, are destitute of ductility. But this distinction, though accurate enough, is insufficient to divide all metallic matters into two classes; for, from the amazing ductility of gold to the singular brittleness of arsenic, we find all metals possessed of this property,—varying in them indeed by sensible degrees: and the difference between the ductility of gold and that of lead is perhaps still more

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considerable than that which subsists in this respect between lead and zinc, which is reckoned a semi-metal, or between zinc and arsenic. So imperceptible are the gradations by which nature passes from one body to another, rising from the lowest to the highest in the system of things.

Metals, considered with respect to their ductility, may be arranged in the following order. Gold is the most malleable of all metals: silver, copper, iron, tin, and lead, follow in the order in which they are here expressed. The semi-metals have been considered as destitute of ductility. We shall see, however, that mercury and zinc possess this property in a certain degree. As to tenacity, gold possesses this property likewise in the most eminent degree; next follow iron, copper, silver, tin, and lead. We know not well in what degree platina possesses this property.

Metallic substances are susceptible of a regular form, which is sometimes conferred on them by the hand of nature; and they readily receive it from art. Naturalists have long been acquainted with this property of metals; native bismuth, virgin silver, with some other metals, are of a regular form in their natural state. Even the alchemists painfully observed the ramified or stellate figures on the surface of antimony and bismuth. M. Baumé, in his rational and experimental chemistry, informs us, that metallic matters, after being melted, assume, if slowly cooled, a regular symmetrical arrangement. The Abbé Mongez, regular canon of St Genevieve, has made a series of inquiries and experiments on the crystallization of metallic matters. M. Brongniart, lecturer on chemistry in the King's garden, has also turned his attention to this object; and many other chemists have repeated their experiments. The

general result is, that all metals are susceptible of crystallization; and though the crystalline form of some among them may appear different, most of them exhibit the same octohædral form, with some variety of modifications.

Some metallic matters have both taste and smell; such as arsenic, antimony, lead, copper, tin, and iron. These properties are invariably met with in all the metals that are most liable to alteration; sometimes even in so eminent a degree, that they corrode and entirely destroy the organs of animals.

§ 2. *The Natural History of Metallic Substances.*

METALLIC substances exist in the interior parts of the earth in four different states. In the first, the metal is virgin or native; that is, possessed of all its properties. Gold is always found in this state; silver, copper, mercury, bismuth, and arsenic, are often found in their native beds in a state of equal purity: Nature seldom presents us with iron, and still seldomer with lead, zinc, antimony, &c. in this state.

The second state in which metallic substances are found is that of *calces*, or oxides; in which state they have not the appearance of metals, but rather resemble ashes or earthy matters. Copper is often found in the state of a green or blue oxide; iron in a yellow, red, or brown oxide; lead in a white, grey, yellow, reddish, and even nitrous oxide; zinc in the state of

calamine; cobalt in red flowers; arsenic in a white oxide, &c.

The third state natural to metals, that in which they are commonly found, is in ores. In this state the metallic substance is combined with a combustible matter, which renders it incapable of exerting its properties till it be separated from that matter. This matter, which is called the *mineralizer*, is either sulphur or some other metal. Some chemists assert, that sulphur is the most common mineralizer. It is united with silver in vitreous silver ore. Copper ores always contain a very large proportion of sulphur. Iron is combined with this substance in the martial pyrites; lead in the galena; mercury in cinnabar; zinc in blend; lastly, bismuth is sometimes, and arsenic often, found in union with sulphur.

It is proper to observe, that all metals have not the same affinity with sulphur. Some of them contain a great quantity, and are easily deprived of it. Their metallic lustre is but little altered by it. Copper, lead, and antimony are of this character. Others again contain but a small portion of sulphur; but that so intimately united with them as to destroy all their metallic properties: cinnabar affords an instance of this fact.

One metal is sometimes in union with another; but arsenic is the great mineralizer. Iron, tin, and cobalt are often found in union with arsenic; sometimes a metal is united with both sulphur and arsenic at the same time; as for instance, in the ore of red antimony, and in red silver. Lastly, there are some metallic ores which consist of several metals, with several mineralizing substances, such as grey copper ore, grey silver ore, and some others.

The fourth state in which metals are found in the bowels of the earth is in combination with acid saline substances. The sulphuric acid is often found in combination with metals: the oxides of zinc, lead, copper, and iron, are generally in the state of sulphates: the carbonic acid is one of the common mineralizers of metals: the muriatic, the arsenic, and the phosphoric acids have been within these few years proved to contribute at times to the same end.

Metallic substances are not nearly so copious as stony matters in the terrestrial globe. The state in which mineralized metals are most commonly found is in veins obliquely intersecting the strata of earths and stones of which mountains are composed. Metals in the state of oxides or salts are often found in masses, which have been carried down, and sometimes crystallized, by water. Some metallic ores are found in shapeless lumps; these owe their formation to some singular accidents.

Veins of metal run between stony matters, which seem to have been formed at the same period. These are generally quartz and spar, and form two strata: the one lying beneath the vein of ore is called *the bed*, the other, which covers it above, is called its *roof*. These stones constitute what is called the *gangue*, or *matrix of the mine*, which must not be confounded with the mineralizer; for the mineralizer is so intimately united with the metal, that it cannot be separated from it otherwise than by a chemical process; whereas the gangue may be separated by a mechanical operation. The gangue consists of crystallized stones; and is therefore to be distinguished from the rock which forms the mass of the hill through which the mine runs. Veins of metal are

divided into *rich* or *poor*, *large* or *small*, *straight* or *crooked*.

Metallic ores appear to owe their formation entirely to water. Most of them are in crystals, or mixed with substances which would have suffered an alteration of nature, if they had been exposed to the action of fire, such as calcareous stones and sulphur. We find likewise among them bodies which still exhibit a vegetable or animal organization, which would also have been destroyed, had it been exposed to the action of fire. There are perhaps some ores which owe their formation to fire: such as the specular iron ore of Mont d'Or in Auvergne. But such instances are rare.

Mines are more generally found in hills than in plains, and almost always in hills forming a continued range. It is observed, that plants growing on hills which contain metallic matters are never luxuriant, but dry and dwarfish: trees in such a situation are crooked and ill shaped: snow melts there almost as soon as it falls; and the sand is metal-coloured. Springs of metallic mineral-water are found in the neighbourhood. By examining the waters of these springs, and the sand over which they flow, it may be determined with a good deal of certainty whether they communicate with veins of metallic matters. When veins of metal appear near the surface, such an indication may be considered as a good reason for piercing the ground to a greater depth. The boring instrument brings up specimens of the substances which compose the interior part of the mountain, and of the metallic mineral matter which it contains; thereby showing the nature of that matter, as well as the resistance, which must be overcome in order to penetrate to it.

§ III. *Of the Art of Assaying Ores, or Docimasia.*

WHEN a certain quantity of ore is obtained, it is next to be assayed, in order that its nature may be exactly determined. This assaying of ores is one of the most important branches of chemistry, and is known by the name of *docimasia*. Every different ore must be assayed in a particular manner: yet there are certain general operations common to all processes of assaying.

Specimens of the ore are first selected from among the richest, the poorest, and those of a middle nature between the two. This selection is absolutely necessary; for if only a rich specimen were assayed, too flattering hopes might be excited; were the specimen assayed from the poorest, the result might be too discouraging. The specimens thus selected are piled one above another, and well washed with water. The fluid carries off the gangue in powder, while the more ponderous mineral remains in the bottom of the vessel. The ore thus washed must next be roasted with due care, in order that as much as possible of the mineralizer may be carried off by sublimation: the mineral when subjected to this operation must be inclosed in a small earthen pot covered over with another. This is a necessary precaution, as some ores burst into pieces when exposed to the action of fire, and fly out of the vessel if it be left open; and such an accident would render the result quite uncertain. When this roasting is performed in the open air, it generally reduces the

metal to an oxide; and if it be of a volatile nature, even drives off a part of it; and therefore we would rather advise the roasting of ore in a stone retort. This process is indeed more tedious and difficult; but it discovers the nature and quantity of the mineralizer, affords a much more accurate analysis of the mineral under examination. When an ore has been kept red-hot, till it cease to exhale vapours, the roasting is then finished. The ore was weighed before and after being washed, in order that the quantity of its gangue might be exactly determined; and it is to be again weighed after the roasting, in order that it may be known how much it lost by the operation.

After being roasted, the ore must next be melted. For this purpose, it is mixed with three parts of black flux and a little decrepitated muriate of soda: the mixture is put into a crucible, which is covered close with a lid, and placed in a good fusing furnace. The alkali of the black flux melts the metal, and absorbs any part of the mineralizer which may still remain in the ore. The coal of the tartar which is found in the black flux serves to reduce the oxide of the metal, by absorbing its oxigene. The muriate of soda hinders the mixture from suffering any loss while in fusion; because being, when melted, lighter than any of the other-matters, it always occupies the upper part of the crucible, covers the mixture, and is the only one of the substances of which any part is lost.

When the fusion is finished, the contents of the crucible must be permitted to cool slowly. The matter may be inferred to have been completely melted, if the metal be united in one lump, the superior surface of that lump being of a convex form; if no grains of it appear intermixed with the scorizæ; and if the scorizæ be

be united in one compact, uniform, vitreous mass, covered over with a crust of melted marine salt. The lump of metal is to be carefully weighed, and the proportion in which the metal exists in the ore is then discovered.

But some ores are harder and more refractory. Fluxes of a more active nature, and those in greater quantity, must then be employed; such as borax, pounded glass, fixed alkali, &c. The same mineral often contains an intermixture of perfect and imperfect metals. These may be separated by heating the lump of metal in the air. The imperfect metal is converted to an oxide, and carried off, leaving the perfect metal in a state of purity. This operation bears the general name of refining. The perfect metal obtained by this process is almost always a mixture of gold and silver. These two metals are separated by a solvent which acts on the silver, leaving the gold uninjured: this operation is called *parting* them. The residues of all these processes should be weighed with the assay-balance.

Accurate as this series of processes may appear, it is often of less utility than one less nicely conducted; for where works of this kind are conducted on a great scale, cheaper materials are used, and less caution is observed. Ore is then to be assayed by melting it on coals in a fusing furnace. The coals reduce the metallic oxide; and the fixed alkali, which is produced as they burn, absorbs part of the mineralizer. It is sometimes found necessary to add a small quantity of filings or scoriæ of iron, in order to facilitate the fusion of very refractory ores.

There is a method of assaying metals in the humid way, which may be employed to discover what metals are contained in pieces of ore meant to be laid up in

collections of the objects of natural history. A small bit, broken off from the piece of ore, is digested among acids, which dissolve the metal, and separate the mineralizer. The salt produced by the union of the metal with the acid shows the quality of the metal. But as all metals are not subject to the action of acids, only certain ores can be assayed in this manner. Bergman has written an excellent dissertation on the assaying of metals in the humid way, which the reader may consult with advantage.

§ IV. *Of the Art of Extracting and Purifying Metals in the great way, or of Metallurgy.*

WHEN it appears from a particular assay, that the working of a mine is likely to be profitable, the following train of operations are then to be employed for the purpose. A perpendicular square pit is dug in the ground, large enough to admit straight ladders on which the workmen may go down and come up. An axis is usually placed over the mouth of the pit, for the purpose of raising up buckets filled with the mineral; pumps too are sometimes put into it for carrying off the water. If the mine be so deep that one perpendicular pit cannot be carried down so far as to reach the floor of the ore, an horizontal drift is formed, at the end of which a new shaft is sunk and this is done repeatedly, till the last shaft penetrate to the bottom of the mine.

If the rock through which the works are carried be so hard and firm as to be in no danger of falling down,

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there will then be no occasion for propping it with any artificial support. But if they be cut through soft stone, or earth likely to crumble down; it will then be necessary to prop the galleries or drifts, and to line the shafts with planks.

It is an object of consequence to procure regular supplies of fresh air in mines. Where it is practicable to open a passage from the bottom of a shaft, which may communicate with the plane below, a current of air is easily produced. Where this cannot be effected, a new shaft is sunk at that part of the gallery which is most distant from the former shaft. When one of these two shafts is higher than the other, the air easily circulates: but if they be equally high, a current of air cannot be produced. When the last is the case, a fire is kindled in a furnace over the mouth of one of the shafts, and sufficient supplies of fresh air are thus conveyed regularly into the gallery.

Water is very troublesome in mines. If it flow slowly through the earth, it is then conducted in a channel along the floor of the mine, and conveyed by a sloping drift into the next river. If it rise in greater abundance it is carried off by pumps. Sometimes when a rock is cut, a quantity of water bursts out, sufficient to fill all the galleries in an instant. The resounding of the rock when it is struck, warns the workmen before this event take place; and they prepare for it by forming a door in one of the galleries: one of the miners cuts the rock to give vent to the water, and instantly retires, shutting the door, which hinders the water from overtaking him.

Vapours consisting of carbonic acid and hydrogenous gas issue from mines, and are either disengaged or formed by

by the mutual re-action of the mineral and metallic matters. The fires which are necessary to soften the rock, generally contribute to the disengagement of those gaseous substances; the dangerous effects of which cannot be otherwise prevented, but by rapid currents of air, or by detonation.

When the mineral is dug and brought out of the earth, it is then pounded, washed, roasted, melted, and refined. It is pounded by large knockers moved by water: these are called (in French) *bocards*. When it is pounded, it is put on inclined tables to be washed, in order that the water may run off, and carry with it the gangue. Ores containing much sulphur should be roasted in the open air; those which contain but a little sulphur may be roasted in the furnaces in which they are to be afterwards melted. Some ores melt by themselves; others require fluxes to dispose them to fusion, and must likewise be put in contact with charcoal. Furnaces for fusion are of various kinds, according to the country and quality of the ore. Furnaces for refining are constructed nearly in the same manner as the others. Sometimes the same furnace serves for both operations. When metals are thus reduced, there are almost always several of them intermixed together. They must then be separated by processes entirely of a chemical nature, which shall be described when we treat separately of the different metals.

§ V. *Of the Chemical Properties of Metallic Substances.*

ALL the chemical properties of metallic substances concur to represent them as simple matters, not liable to decomposition. The alterations which they suffer from heat, air, and saline substances, are always owing to combination; not one of those alterations can with any reason be compared to an analysis, as we are about to show by a particular account of the phenomena which they exhibit on such occasions.

Light appears to alter the colour and lustre of some metallic substances. Some metals, when inclosed in transparent vessels, are sullied, and acquire gradually a new colour, which deprives them of their brilliancy. This kind of alteration has not been farther observed.

Heat effects some changes on the aggregation of metals, with various degrees of quickness and facility. All metallic substances are liable to melt on being heated in close vessels; some of them long before becoming red-hot, others at the very instant when they become red, and others not till a considerable time after. There are as many different degrees of the fusibility of metals as there are different kinds of metals. If left to cool after melting, they assume a crystalline form. If urged with a violent fire, they boil like fluids, and are reduced to vapour. Mercury has long been known to possess these properties. Goldsmiths often see gold and silver boil when in fusion. M. Buffon observed,

served, that when silver plates were exposed to the focus of a large concave mirror, a white smoke arose from the surface of the plates. Messrs Macquer and Lavoisier having cupelled silver in the focus of Tschirnhausen's lens, saw the metal exhale in smoke: a plate of gold exposed to that smoke was completely silvered over. Gold exposed to the same focus likewise exhaled a smoke which gilded silver. The chimnies of goldsmiths and assayers are filled with gold and silver in smoke. Copper, tin, lead, zinc, antimony, bismuth, and arsenic, may be volatilized with great ease.

The surfaces of all melted metals are convex; and when they are in very small masses, they compose perfect spheres. This effect is owing to the affinity of aggregation, which causes the particles of metals mutually to attract each other, and to the weakness of their tendency to combine with the body on which they are placed. This is a general property of fluids, and may be observed of oil in respect to water, and of water in respect to fat bodies.

When metals are exposed in the air to the action of fire, they suffer considerable alterations; some sooner, some later. Those which suffer no sensible alteration on such occasions are called *perfect metals*: those again which are entirely deprived of their metallic properties by this process are called *imperfect metals*. This alteration of metallic matters which we call *oxidation*, is a real combustion. Like the combustion of all other combustible substances, it cannot be effected without the help of air. And when it has taken place for some time in a certain quantity of air, it cannot be continued, at least without a supply of fresh air. The air in which metals are burnt becomes mephitic. The combustion

of metallic substances is attended with a flame more or less lively. Zinc, arsenic, iron, gold, and silver, display a distinct flame; such likewise is that of lead, tin, and antimony, when they are exposed to an intense heat. The longer metals are exposed to the action of fire in contact with air, the more entirely are they divested of their metallic properties. Some of them seem to acquire the characteristics of earthy matters; and in that state they are called *metallic earths* or *calces*. But the name of *metallic oxides* is more expressive of their real nature; for it is fully demonstrated, that those burnt metals are not earths, as they were a few years ago believed to be, but combinations of the metals with oxygen. Metallic oxides have no longer the brilliancy and fusibility of the original metals; nor have they any longer an affinity even with the metals to which they owe their formation. If urged with fire, they are volatilized, or melt into glass. This glass is the more transparent and infusible, in proportion as the metals have been more completely oxidated; that is, in proportion as they contain a greater quantity of oxygen. Metallic oxides combine with saline and earthy matters. Several of them possess the characteristics of saline substances. When arsenic is highly oxidated, it becomes a peculiar acid; the properties of which have been examined by Scheele and Bergman. Rouelle informs us, that the oxide of antimony dissolves in water like arsenic.

Some metallic oxides are reduced to metals when exposed to the action of fire, and give out, as they are reduced, an aeriform fluid, which is very pure vital air. We are indebted to M. Bayen for the first certain information which we obtained on this head. He observed, that when oxide of mercury was heated in close

close vessels, it gave out a good deal of air, and was then reduced to the state of running mercury.

Dr Priestley, on examining this air, found it to be much purer than atmospheric air; and at the period of this discovery we may date the rise of that accurate knowledge which we at present possess of the laws of the calcination of metals. Let us take a short review of the phenomena which attend this operation. A metal cannot be *calcined*, unless it be in contact with air. The greater the quantity of the air brought into contact with the metal, the more completely is the metal *calcined*. A given quantity of air cannot serve to *calcine* any more than a given quantity of metal; as M. Lavoisier has ingeniously shown by *calcining* lead by means of a reflecting mirror in a bell-glass containing a known portion of air. When a metal is *calcined*, it absorbs a part of the surrounding air; for the mercury over which it is *calcined* rises in the vessel in proportion as the *calcination* proceeds. It is to this absorption of oxygen that metallic calces owe the increase of weight which they gain by *calcination*; for when it is extracted from the oxide of mercury, that oxide returns to the state of a metal, and suffers a loss of weight precisely equal to the weight of the vital air obtained from it by distillation. These phenomena show evidently that *calcination* is nothing but the combination of the metal with the base of pure air, or the oxygen contained in the atmosphere. This combination is often effected merely by the contact of air and water in metals liable to rust. The reason why heat is necessary to the oxidation of most metals is, because by diminishing the aggregative force by which the integrant parts of those bodies adhere together, it increases in the same proportion their force of affinity or combination; and thus promotes the combination

combination of the oxigene with the metal. In this operation, therefore, as in most solutions, heat is no more than an auxiliary. The air which has been once employed in the oxidation of a metal, can no longer contribute to maintain combustion; because it is deprived of its vital air, the principle which rendered it serviceable to combustion and respiration. The greater the proportion of the vital air contained in the atmospheric fluid, so much the sooner will it reduce a given quantity of metal to an oxide. I have often observed, that by immersing melted lead, bismuth, &c. in a vessel filled with vital air, a much greater quantity of metallic oxide may be obtained in a given time than if the metals were exposed for the same space to the action of atmospheric air. All of these facts, and a great many more, which will be found under the history of the different metals when we come to treat of them separately, concur to prove that a metallic oxide is nothing but a chemical combination of a metal with the oxigene of the atmosphere; that calcination is merely the act by which this combination takes place; and that as vital air is fixed on the occasion, what remains of atmospheric air after it has contributed to the calcination of a metal is nothing but azotic gas.

The reduction of metallic oxides by the use of combustible matters, farther illustrates and confirms this theory. To reduce a metallic oxide to a metal, it is often found necessary to heat it in a close vessel with some combustible matter, such as fats, oils, charcoal, &c. On all such occasions the metallic oxide is decomposed, and loses the oxigene to which it owed its character as such. In order to understand what passes on this occasion, we must reflect, 1. That metals are not the most combustible bodies in nature; or, what

is

is the same thing, that metals have not the greatest possible affinity with oxigene. 2. That animal or vegetable combustible matters have a stronger affinity with oxigene than metallic substances have. 3. That, of consequence, when a metallic oxide is reduced with the help of charcoal, the charcoal having a greater affinity with oxigene, or being more combustible than the metal, robs the oxide of the principle to which it owes its character, and causes it to pass into the state of a metal. And operations of this kind succeed best in close vessels; because when the combustible matter is not in contact with air, it cannot burn without absorbing the oxigene of the oxide. For this reason the pure carbonaceous matter which combines with the oxigene of the metallic substance, is changed into carbonic acid during the reduction of the metal.

Having given the history of the calcination of metals according to the modern theory, we cannot avoid taking some notice of Stahl's doctrine on this head, which was almost universally received among chemists till the period of the late discoveries concerning air and combustion. Stahl considered metallic substances as compounds of peculiar earths with phlogiston. *Calcination* was, in his opinion, merely the disengagement of the *phlogiston*; and he thought that the reduction of metals restored to them the principle which they had lost by *calcination*. This theory is directly contrary to the modern theory: it represents metals as compound substances; whereas the doctrine at present received considers them as simple bodies. According to Stahl, they lose, when *calcined*, one of their component principles; but the facts on which the modern theory is founded, prove that they enter, on that occasion, into a new combination. Lastly, That great man

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imagined, that metallic oxides regained by reduction the *phlogiston* of which the metals had been deprived by the action of fire: but the moderns have shown reduction to be merely the separation of the oxigene which entered into combination with them when they were calcined.

After this slight comparison of the two theories, let us attempt to show which of them is supported by the greatest number of facts. Stahl, while he was so eager to demonstrate the existence of *phlogiston* in metals, seems to have overlooked the influence of air on their calcination. Beccher, Ray, Boyle, and several other chemists, had, however, suspected, before his time, that this element was the principal agent on the occasion. And however satisfactory the theory of Stahl may have appeared till the æra of the new discoveries concerning air, yet it must always have appeared inconsistent with those facts, which prove that air acts, and is a necessary agent in the calcination of metals. Stahl's theory was therefore imperfect, as being insufficient to explain a number of the phænomena. It gives no reason, for instance, why metallic oxides are weightier than the metals before calcination. It is impossible to conceive how any body can acquire additional weight, in consequence of losing one of its constituent principles; and as gravity is one of the essential properties of all bodies, the ingenious explanation of this phænomenon which M. de Morveau has given in his Dissertation on *Phlogiston*, cannot be considered as fully satisfactory; especially since it has been discovered that there is a portion of air in metallic oxides. From these facts, therefore, it appears that the pneumatic theory has by much the advantage over Stahl's. Macquer, with a judicious discretion which we cannot

sufficiently praise, attempted to reconcile the modern discoveries with the doctrine of *phlogiston*. According to that celebrated chemist, metals never lose their *phlogiston* or suffer *calcination* but when the pure air of the atmosphere is precipitated, and combined with their substance; the light which they contain is then disengaged: and when they are reduced, light, with the help of heat, expels the pure air which had entered into combination with them, and assumes its place. So that light and pure air may be considered as mutually precipitating one another. But as light, and that principle to which Stahl gave the name of *phlogiston*, have not yet been shown to be the same, and as the existence of light as a principle in combustible bodies is equally uncertain, Macquer's opinion can be viewed in no other light but as an hypothesis, which may be entirely overlooked, but cannot be admitted as well founded.

It is therefore at present an incontestible fact, that metallic oxides are compounds of the metals with oxygen: it is much to be wished that we knew the various elective attractions subsisting between that principle and the different metallic substances. M. Lavoisier has already turned his attention to this important object of chemical research: but his experiments are not yet sufficiently numerous, nor their results sufficiently accurate, to enable us to enter here into minute particulars on this head.

Metallic substances are altered by air; their surfaces lose their lustre, and are sometimes covered over with rust. Chemists consider rust as a metallic oxide. We will, oftener than once, have occasion to review this subject, and to show, that water in vapour oxidates a number of metallic substances, and that the carbonic

acid

acid of the atmosphere combines with them after their calcination.

Water dissolves certain metals; on others it has no power of action: when in vapour it contributes highly to the formation of rust on those metals which are susceptible of it. We know, from M. Lavoisier's late discoveries, that it acts with great energy in effecting the oxidation of the most combustible metals, such as zinc and iron; and that it is decomposed on such occasions into oxigene, which combines with these metals; and into hydrogene, which is disengaged in union with a large proportion of caloric; and of consequence in the form of a very light gas.

Earthy matters appear to have no power of action on metallic substances; but they may be combined with metallic oxides by fusion.

We are entirely ignorant of the manner in which the alino-terreous matters act on the substances which we are now examining.

The alkalis dissolve some metals; they act, however, but weakly on most of them. Water or air appear to contribute greatly to the oxidation of those metals which are liable to such a change by the action of alkalis.

The acids produce a much greater alteration on metallic substances, dissolving them with more or less difficulty. The sulphuric acid then produces either hydrogenous or sulphureous gas, according as it is diluted with water or concentrated. In the first instance, the water is decomposed, and gives out hydrogenous gas, while it communicates its oxigene to the metals: in the second, the acid itself is decomposed; and while part of its oxigene combines with the metallic substan-

ces, the rest remaining in union with the original proportion of sulphur, constitutes by that means sulphureous acid gas. When the sulphuric acid is in either of these instances saturated with a metallic oxide, it forms what was formerly known by the name of *vitriol*; which when in crystals is to be considered as a compound of four bodies, namely, metal, oxigene, sulphuric acid, and water. These metallic sulphates are subject to many varieties in their colour, tendency to crystallization, solubility in water, susceptibility of decomposition by heat, by vital air,—the oxigenous part of which they absorb, by the alkalis which separate the metallic oxides, &c.

The nitric acid appears to act more quickly on metals than the sulphuric acid; but it generally adheres to them with much less force. While it acts on these substances, a considerable quantity of nitrous gas is disengaged; the metal is more or less oxidated; and is either precipitated, or remains in union with the acid. Stahl ascribed this effect to the disengagement of the phlogiston of metals. Modern chemists now think that it is owing to the decomposition of the nitric acid, and the separation of part of its oxigene from the azote, in other principle; for we have elsewhere shown these two gaseous bodies to be the component principles of the nitric acid. Nitrous solutions of metals, or metallic nitrates, are more or less liable to crystallization, and to decomposition by heat, air, or water. Alkaline matters separate the metallic oxides: the nitric, like the sulphuric acid, has various degrees of affinity with the different metals. M. Proust has discovered that a number of metallic substances are inflamed when they come into contact with this acid.

The muriatic acid seldom acts with much energy

energy on metals. The water which is in union with it, first oxidates the metals, producing by this means the hydrogenous gas which is disengaged from solutions effected by this acid. These solutions effected by the muriatic acid are generally more permanent than either of the two last-mentioned acid solutions of metals, and usually more difficult to decompose by heat. Sometimes they afford crystals, but seldom without considerable difficulty. The muriatic acid has a greater affinity than either of the two preceding acids with most metallic substances; which enables it to decompose both sulphuric and nitric solutions of metals. Metallic muriates are often volatile.

The oxygenated muriatic acid oxidates most metals with a good deal of energy, on account of its containing an excess of oxygen, and that not very closely united with it. It dissolves them in the same way in which water dissolves salts, without effervescence.

The carbonic acid acts but faintly on metals; yet Bergman has shown it to be capable of combining with most of them. In nature we often find metals in combination with this acid; and these compounds are sometimes in crystals: they are known by the name of *sparry metal*, such as sparry iron, sparry lead. But we rather give them names analogous to those of the other salts formed by this acid, calling them *carbonate of iron, carbonate of lead, &c.*

The fluoric and the boracic acids have an equal tendency to combine with metallic matters; but the compounds which they then form are but little known.

Some among the combinations of metals with acids are susceptible of crystallization; others cannot be made to assume any regular form. Fire decomposes some of

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them;

them; others suffer no alteration from that agent. Most of them are altered by air, the oxygenous part of which they absorb. All of them are more or less soluble in water, and liable to decomposition by that fluid, when a great quantity of it is caused to act on them, as has been observed by Macquer. All of them are precipitated by aluminous earth, barytes, magnesia, lime, and the alkalis; which substances have, in general, a stronger affinity than metallic oxides with the acids.

When several metals are employed to separate other metals from their solutions, the metals that are precipitated regain their metallic form and lustre; because the oxygen which was united with them, while they were in a state of solution, is separated and combined with the precipitant metal, which is in its turn dissolved in the acid. M. Lavoisier, therefore, with good reason considers these precipitations of metals by one another, as owing to their having various affinities with the oxygenous principle.

Neutral salts suffer but little alteration from metallic matters when the two substances are brought together in the humid way; but when a mixture of a salt with a metal is heated, several of the salts are liable to be decomposed. Several sulphuric salts form sulphur on such an occasion. M. Monnet is the only chemist who has observed antimony to be capable of effecting the decomposition of neutral salts in this way. In a series of experiments on this subject, I have found, that several other metals, such as iron, zinc, &c. decompose sulphate of potash, &c.

Nitre detonizes with most metallic substances, and oxidates them with more or less energy. The cause of this phenomenon is, that oxygen has a stronger affinity

nity with most metallic substances than it has with the azotic principle. Metals oxidated by this salt are called *metallic oxides* by nitre. The alkaline base of this salt often dissolves a part of the oxides.

Ammoniacal muriate is decomposed by several metals, and by the oxides of almost all metallic substances. Bucquet, who made a series of experiments on this subject, remarked, that all metallic substances on which the muriatic acid is capable of acting without an intermedium, are liable to be entirely decomposed by ammoniacal muriate; that hydrogenous gas is disengaged when these decompositions take place; and that metals which do not admit of solution by the common muriatic acid, are not liable to this decomposition. The ammoniac obtained on these occasions is always very pure and caustic.

Almost all combustible mineral matters combine readily with the metals. Hydrogenous gas colours them, and reduces some of their oxides; having, as Dr Priestley has proved by some very ingenious experiments, a greater affinity with oxigene than what most metals have. The reduction of metallic oxides by hydrogenous gas is accompanied with the production of a certain quantity of water by the combination of the hydrogen with the oxigene disengaged from the metals.

Sulphur combines with most of the metals: the combination of sulphur with a metal forms an artificial ore. When ores of this kind are moistened, or exposed to humid air, they are vitriolized, or changed gradually into metallic sulphates. Alkaline sulphure dissolves any metal. Sulphurated hydrogenous gas colours and decomposes metallic oxides, reducing them at the same time by the absorption of their oxigene.

Metals combine more or less readily with one another: the results are mixtures; the properties of which render them very useful in the arts.

§ VI. Methodical Division of Metallic Substances.

AS metallic substances are pretty numerous, it appears necessary to divide them into certain orders, and to distinguish metals possessing similar properties from those of which the properties are different. We may consider ductility as the first characteristic of metals. Such metallic substances as possess not this property, or possess it but in a very inferior degree, have received the appellation of *semi-metals*. Those, again, which are highly ductile, are called *metals*. The semi-metals are either very brittle under the hammer, or in a small degree malleable. This distinction occasions a subdivision of these substances. Metals may be also subdivided, in respect of the manner in which they are affected by fire. Some metals, when heated in the air, are easily oxidated: others again suffer no alteration when they are treated in the same manner. The former are *imperfect metals*; the latter *perfect metals*. That we may not multiply these divisions as we proceed in our history of metallic substances, we shall here give a table, in which metals are classed according to their natures.

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Others hav

Zinc.

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Metallic Substances are either

Scarcely ductile,

SECT. I.

Semi-metals.

DIVISION I.

Some of them break into pieces
under the hammer.

Arsenic.

Molybdena,

Tungsten.

Cobalt.

Bismuth.

Antimony.

Nickel.

Manganese.

DIVISION II.

Others have a sort of semi-ducti-
lity.

Zinc.

Mercury.

Or highly ductile.

SECT. II.

Metals.

DIVISION I.

Some are easily reduced to oxides,
when heated in the air.

Imperfect Metals.

Lead.

Tin.

Iron.

Copper.

DIVISION II.

Others cannot be reduced to ox-
ides by the same process.

Perfect metals.

Silver.

Gold.

Platina.

C H A P. VI.

Of Arsenic and its Acid.*

ARSENIC is placed at the head of the semi-metals, because it bears a considerable relation to salts. Kunckel thought it to be a coagulated aquafortis. Becher and Stahl considered it as a saline matter. Scheele has proved, that it forms a peculiar acid; and Brandt and Macquer have shown it to be a genuine semi-metal. When arsenic possesses all the properties natural to it, it has all the characteristics of a metallic matter. It is then perfectly opaque, and has the gravity and lustre which distinguish those substances.

Native arsenic is often found in black masses, almost without lustre, and very heavy: it has sometimes the distinguishing lustre of metals, and it then reflects the colours of the rainbow: its fracture is still more brilliant, and shows it to consist of a great number of small scales. When those scales or shells are observable on the exterior part of the mass, it is then called *testaceous arsenic*.

* We give the name of *arsenic* to the semi-metallic matter commonly known by the name of *regulus of arsenic*. That denomination is improper and ought to be laid aside. What is called *white arsenic* is the oxide of this semi-metal. A.

arsenic, or improperly *testaceous cobalt*, because formerly when the metallic character of arsenic was unknown, and its oxide was obtained in a large proportion from cobalt ore, testaceous arsenic was thought to be cobalt ore. Virgin arsenic is very easily known when it has the metallic lustre, and is in small scales; but when it is black, and its texture close grained, the only way of distinguishing it is by its gravity, which is very considerable, and by observing whether or not it is dispersed in white smoke, having a strong smell of garlic when laid on burning coals. Great plenty of this last kind is found at *St Marie aux Mines*. It is mixed with grey silver ore. It is likewise found in the cobalt mines of Saxony, and at Andrarum in the province of Schonem in Sweden.

Arsenic is sometimes found in nature in a white oxide, which is also of a vitreous appearance, but oftener in the form of light dust, or mixed with some particular earths. This oxide is likewise found at *St Marie aux Mines*. It is known by its white smoke, and by the garlic smell which it diffuses when thrown into the fire.

Arsenic is often combined with sulphur; it then forms *orpiment* and *realgar*, or the yellow and the red sulphurated oxides of arsenic. Native *orpiment* appears in yellow, brilliant, and seemingly talcky masses, of various sizes and various degrees of brilliancy: it is often mixed with *realgar*, and it sometimes approaches to green. *Realgar* is of a red colour, more or less lively and transparent, and often crystallized in bright needles. A good deal of it is found at Quito and on Mount Vesuvius. The only difference between these two substances seems to be, that the one has been formed by a more intense heat than the other.

Mispikel,

Misspikel, or arsenical pyrites, is the last ore of arsenic. It contains that semi-metal in combination with iron. *Misspikel* is sometimes found in cubic crystals, but oftener without any regular form. This ore is of a white, *chatoyant* colour. Wallerius calls it white cubic arsenic.

Arsenic is also found among cobalt, antimony, tin, iron, copper, and silver ores.

Pure arsenic, called also *regulus of arsenic*, is of a blackish grey colour, and reflects the colours of the rainbow. It is very ponderous, and very friable.

When arsenic is exposed to fire in close vessels, it is sublimed, but not decomposed; It is even one of the most volatile metallic matters. When slowly sublimated, it crystallizes in triangular pyramids. When arsenic is heated in the air, it is very soon converted into an oxide, and dissipated in the form of a white smoke, which exhales a strong smell of garlic. Red arsenic burns with a bluish flame. On that occasion, it combines with the oxygen of vital air, and forms a compound known by the name of *white arsenic* or *calx of arsenic*, and which we call oxide of arsenic. This is the reason why arsenical ores of cobalt give out in the furnace a great deal of white smoke, which is condensed in the chimney into a white, ponderous, vitrified matter, that is deposited in layers, and is sold very improperly under the name of arsenic. It is properly an oxide of vitreous arsenic.

The oxide of arsenic is essentially different from the oxides of all other metallic substances: it has a very strong, and even a caustic taste; it is a strong poison. When exposed to fire in close vessels, it is volatilized by a moderate heat into a white crystalline powder, known by the name of *flowers of arsenic*. When the heat is a little stronger, it is vitrified as the sublimation

takes

takes place. The glass produced is very transparent, and crystallizes into flat triangular solid figures, with truncated angles. It very soon loses its transparency in the air. No metallic oxide is really volatile of itself; that of arsenic is the only one which exhibits such a property; it is at the same time very fusible and very vitrifiable. Beccher attributed the gravity and volatility of arsenic to a peculiar principle, which he called *mercurial* or *arsenical earth*, and of which Stahl has not been able to demonstrate the existence.

Arsenic in the state of regulus does not act in a sensible manner on combustible bodies; but the oxide of arsenic produces a sensible alteration upon them, and at the same time resumes its metallic lustre. Stahl thought, that, on this occasion, the combustible body restored to the arsenic the phlogiston which it had lost by calcination: But the moderns have proved, that the oxide of arsenic is a compound of arsenic and oxigene, and that the combustible body, having a greater affinity with oxigene than arsenic has, in consequence of its possessing that property, causes the oxide of arsenic to return to the metallic state. To succeed in reducing oxide of arsenic, it must be made into a powder, and baked into a paste with black soap: this paste is to be put into a matrafs, and placed on a sand bath; a moderate heat must at first be applied, in order to dry up the oil: when humid vapours cease to exhale, the fire must be increased in order to sublime the arsenic; the matrafs is then to be broken, and the upper part of it is found to contain a cake, having the appearance and metallic lustre of arsenic: most of the carbonaceous matter of the oil remains at the bottom of the matrafs.

Arsenic, when exposed to the air, becomes sensibly black. Vitrified oxide of arsenic, on such an occasion,

loses its transparency, and acquires a lacteous appearance, suffering at the same time a sort of efflorescence.

Arsenic does not appear to be liable to suffer from the attacks of water, but its oxide is readily dissolved in that menstruum: Warm water dissolves rather less of it than cold: The solubility of this substance varies also according as it has been more or less perfectly oxidated. When a solution of oxide of arsenic is slowly evaporated, it gives yellowish crystals in triangular pyramids: no other metallic oxide is known to dissolve so readily in water. This property of oxide of arsenic, together with its sapidity, renders it not very different in nature from saline matters.

Oxide of arsenic unites readily enough with earths by fusion; it becomes fixed with them, and accelerates their vitrification: but all glasses into the composition of which it enters are liable to be very soon sullied in the air. It is not known in what manner the saline terreous substances act on arsenic and on its oxide. The caustic fixed alkalis, though they do not act in any sensible manner on arsenic, dissolve its oxide very readily. Macquer, in his ingenious experiments on this matter, (*Academ. Mem.* 1746,) has observed, that when powdered oxide of arsenic is boiled in liquor of fixed nitre, or a solution of caustic potash, it is completely dissolved, and forms a brown gelatinous fluid, the consistency of which gradually thickens. This compound, to which he gives the name of *liver of arsenic*, is not susceptible of crystallization: it becomes hard and brittle: it is liable to deliquiate, and soluble in water: some brown flakes are precipitated when it is dissolved: When urged by a strong fire, liver of arsenic loses the arsenic which it contains. Acids decompose it: Soda mixed in the same manner with arsenic

exhibits the same effects; but its solution afforded Macquer irregular crystals, the form of which he found it impossible to determine.

The sulphuric acid cold, even though it be concentrated, produces no effects on arsenic; but when boiled with this semi-metal in a retort, the acid gives out a good deal of sulphureous gas; after that, a little sulphure is sublimed, and the arsenic is then found to be reduced to an oxide, but without being dissolved. The sulphuric acid likewise dissolves oxide of arsenic when it is concentrated and boiling; but when the solution cools, the oxide is totally precipitated. When it enters into this combination, it becomes fixed in a very considerable degree. Bucquet asserts, that when it is entirely freed of the acid by lixiviation, it regains all its original properties.

The nitric acid, when applied to arsenic, acts vigorously upon it, and reduces it to an oxide. When assisted by a moderate heat, the same acid likewise dissolves oxide of arsenic in a pretty considerable proportion: though saturated with either of these substances, it retains its natural smell: when violently evaporated, it produces a salt which, according to Bucquet, has no regular form, but is said by M. Baumé to be partly cubic and partly cut into diamond points. Wallerius says its crystals resemble those of nitrate of silver. Nitrate of arsenic powerfully attracts the moisture of the air: it does not detonize on the coals, nor is it liable to decomposition by water or acids: the alkalis do not cause it to yield a precipitate; yet, according to Bucquet, they decompose it, for when a nitric solution of arsenic, mixed with an alkaline lixivium, is evaporated, common nitrate and arseniate of potash is obtained. We will hereafter see, that chemists, being all very much

much perplexed with the singular nature of the solutions of arsenic and oxide of arsenic in acids, never discovered what passed when this oxide was combined with the nitric acid; nor once suspected the production of the arsenic acid. Here we would only remark, that the oxide of arsenic deprives the nitric acid of a great part of its oxigene.

The muriatic acid, with the help of fire, dissolves both arsenic and its oxide, according to Bucquet. Either fixed or volatile alkali is capable of precipitating this combination. M. Baumé says, that regulus of arsenic is soluble in the boiling muriatic acid, and afterwards is precipitated in a yellow powder, resembling sulphur. Mess. Bayen and Charlard, in their experiments on tin, have established it as a fact, that, when cold, the muriatic acid is entirely incapable of acting on arsenic; and that when warm, it acts on it but very faintly, in a manner scarcely discernible.

We are perfectly ignorant how the other acids affect arsenic or its oxide. A mixture of arsenic with nitre, put into a red hot crucible, gives a smart detonation: the nitric acid calcines and burns the semi-metal. The fixed alkali, which was the base of the nitre, and the oxidated arsenic, combined in part with the fixed alkali, are found in the crucible after the operation.

A mixture consisting of equal parts of oxide of arsenic and nitre, distilled in a glass retort, gives spirit of nitre in very red vapours. The acid cannot be condensed till a little water be put into the ball of the retort, which gives it a blue colour. Beccher, Stahl, and Kunckel, have described this operation. Macquer repeated it with care; and on examining the residue, which those chemists had made no mention, found to be a peculiar neutral salt, and has given it the name

of *arsenical neutral salt*; it should be called *arsenate* of potash. When this salt is dissolved in water, and the solution evaporated in the air, it gives very regular crystals in tetrahædral prisms, terminating in pyramids with four equal faces. The form of the crystals sometimes varies.

When arseniate of potash is exposed to fire, it easily melts, and remains in a state of fusion without being alkalinized, and without losing any part of its arsenic by volatilization; from air it suffers no sensible alteration. It is much more soluble in water than pure oxide of arsenic; and more of it dissolves in hot than in cold water.

None of the acids decomposes it pure; but what they cannot effect pure, they can perform by double affinity. If a small portion of sulphate of iron or *mar- tial vitriol* be mixed with a solution of this salt, a double decomposition and a double combination follow. The sulphuric acid forsakes the iron in order to combine with the potash, and the arsenic acid is separated from the alkali, and combines with the iron oxide. Combustible matters decompose arseniate of potash with great energy.

The oxide of arsenic likewise decomposes nitrate of soda by distillation, forming with its base arseniate of soda, which, according to Macquer, is very little different from arseniate of potash, and crystallizes precisely in the same manner. This oxide acts in the same way on ammoniacal nitrate, and combines with its base to constitute ammoniacal arseniate. It was thought that a great many precautions were necessary in performing this operation, because in close vessels ammoniacal nitrate detonizes by itself: but M. Pelletier has proved, that even several pounds of it may be made together with-

out any danger. Macquer's discovery of the arseniaceous neutral salt led the way to the discovery of the arsenic acid; for that illustrious person observed and asserted that the oxide of arsenic acted the part of an acid in this salt. But it is to Scheele, as we shall hereafter mention, that we are really indebted for an accurate knowledge of those new combinations.

Oxide of Arsenic does not decompose alkaline muriates. Like arsenic itself, it separates ammoniac from ammoniacal muriate, but not without great difficulty.

The action of combustible mineral matters on arsenic has not yet been examined. It appears, that the oxide of this semi-metal may be reduced by hydrogenous gas, which has more affinity than arsenic with oxigene, or the base of vital air.

Oxide of arsenic combines very readily with sulphur. When these two substances are melted together they form a yellow or red volatile body, the taste of which is rather weaker than that of pure oxide of arsenic, but which is not more soluble in water than the substance. This yellow sulphurated oxide of arsenic has been called *factitious orpin* or *orpiment*: It crystallizes in triangular figures like vitreous oxide of arsenic. When red it is called *realgar*, *realgar factitious rixigal* or *red arsenic*. The name which we give to this compound is red sulphurated oxide of arsenic. Some chemists have imagined it to differ from the yellow or orpiment only in containing more sulphur; but Bucquet has shown, that the compound of sulphur and oxide of arsenic becomes red after being melted; for to expose orpiment to a pretty strong heat is all that is necessary to make it pass into the state of *realgar*. I am convinced that *realgar* is far from being so volatile as orpiment; for when the mixture of oxide of arsenic and sulphur is sublimated

In a matrafs, red fwollen laminæ are found at the bottom, which appear evidently to have been melted. There is no difference between artificial orpiment and realgar and the same substances natural. They are liable to be decomposed by lime and the alkalis, which have a greater affinity with sulphur than the oxide of arsenic has: yet this oxide, like the acids, possesses the property of decomposing alkaline sulphures.

All the properties of the oxide of arsenic concur to show, that when this semi-metallic combustible matter is united with the base of vital air, it acquires the character of a saline substance: The theory which we laid down when treating of salts in general is therefore confirmed by these facts. Macquer, in his valuable discoveries concerning arseniate of potash, observed, as was before mentioned, that oxide of arsenic acted the part of an acid in the composition of that salt: but it was hard to conceive, how that oxide, when dissolved in potash without any intermedium, could differ so considerably from the combination of the same substances produced by decomposing nitre with oxide of arsenic.

The discovery of the oxygenated muriatic acid suggested to Scheele, that something analogous might happen when nitre was distilled with oxide of arsenic. The nitric acid, he imagined, seized what phlogiston still remained in the oxide; upon which the oxide was left in the state of the peculiar acid which we call the arsenic acid. He prepared this acid by a process analogous to that by which he produced the oxygenated muriatic acid. One part of that process consisted in distilling a mixture of the oxygenated muriatic acid with oxide of arsenic. According to him, the muriatic acid then seizes the phlogiston of the oxide, leaving it in the state of an acid. The arsenic acid may be also prepared by distilling six parts of nitric acid

upon one of its oxide. The acid gives out a good deal of nitrous gas; and the oxide of arsenic assumes the character of an acid. It must be exposed for a considerable time to a strong heat, in order that the superfluous nitrous gas may be disengaged.

What happens in these operations is considerably in favour of the modern doctrine. In fact, on one hand, one can scarce agree with Stahl in acknowledging the existence of phlogiston in oxide of arsenic; and again, nothing can be more natural than the manner in which the modern doctrine represents this oxide as passing from an oxide to an acid by the influence of spirit of nitre, or the oxygenated muriatic acid. Oxide of arsenic appears to have a great affinity with oxygen, when it is not already saturated with it. When distilled with the nitric, or the oxygenated muriatic acid, it deprives either of these acids of its oxygen. The more oxygen it contains, the nearer does it approach in nature to saline substances; and when fully saturated it acquires all the distinguishing properties of acids, which, as we have shown above, are nothing but combustible matters combined with oxygen, which communicates to them their saline properties. From this theory it may be easily understood why oxide of arsenic, when not saturated with oxygen, but simply oxidated by fire, does not form arseniate of potash; and why it never composes that salt till after being previously treated with the acids which it decomposes, by depriving them of their oxygen with the help of heat.

The arsenic acid is very different from common oxide of arsenic. Its sapidity is stronger. Fire fixes it; and this process is employed to separate it entirely from any remainder of oxide of arsenic which it may

will retain. It is doubtless by acquiring the properties of an acid that oxide of arsenic becomes of a fixed nature when combined with the sulphuric acid. That acid causes it to melt into a transparent glass: it communicates its fusibility to earthy matters; and it even appears capable of corroding glass. It communicates a faint red tinge to blue vegetable colours. I have observed, that, when exposed to the air, it loses its transparency, wastes away in scaly fragments, which are generally pentagonal, and gradually attracts moisture. It dissolves in two parts of water: It combines readily with lime,—and with barytes and magnesia, but with more difficulty. With the alkalis it forms neutral salts, which, according to Bergman, are decomposed by lime. The same chemist informs us, that barytes and magnesia have likewise a greater affinity with this acid than the alkalis: but a great many more experiments must be made before we can be fully acquainted with all the properties of the arsenic acid. Pelletier prepared this acid by decomposing ammoniacal nitrate with oxide of arsenic. The ammoniacal arseniate thus formed was deprived of its ammoniac by heat; and after it had been for some time exposed to the action of fire, the arsenic acid remained pure and solitary in the bottom of the retort.

Bergman observes, that the specific gravity of arsenic varies from that which distinguishes it in the metallic state, to that which belongs to it when an acid: the following are the gravities which he ascribes to it in its various modifications: regulus of arsenic 8,308: stannous oxide of arsenic, 5,000: white oxide of arsenic 3,706: arsenic acid, 3,391.

Arsenic is made use of in several of the arts, more especially in dyeing. Arseniate of potash is likewise

used; and M. Baumé has long manufactured it for the purposes of the arts.

The facility with which oxide of arsenic dissolves in water, or any aqueous fluid, renders it a very dangerous poison. The following symptoms appear when a person has taken this poison: His mouth becomes dry, his teeth are set on edge, and his throat contracted; he has an involuntary salivation, and an acute pain in his stomach: he feels an extreme thirst and nausea, and vomits slimy bloody matters: he feels at the same time very intense colic pains; his body is bedewed with a cold sweat, and he is agitated with convulsions. These symptoms are soon followed by death; and oxide of arsenic is known certainly to have been the cause by examining the aliments in which it is suspected to have been given. The presence of the poison is determined by drying part of those aliments, and throwing it on burning coals: if impregnated with arsenic it exhales a white smoke, having a strong smell of garlic.

It was formerly the practice to make persons poisoned with arsenic drink milk, or some mucilaginous liquid or mild oil, with a design to relax the viscera, and to dissolve and carry off most of the arsenical poison. Navier, a physician at Chalons, who has laboured to discover some remedy capable of counteracting the poisonous effects of oxide of arsenic, has found a matter which combines with this substance in the human way, saturates it, and almost totally divests it of its causticity. That substance is calcareous or alkaline sulphure; and this sulphure is still better for the purpose if it be impregnated with a little iron. A solution of oxide of arsenic decomposes sulphures without exhaling any smell: the oxide combines with the sulphur to form orpiment, entering at the same time into union

with the iron, if the sulphure contain any. Navier prescribes a dram of *liver of sulphur* in a pint of water, to be taken in glasses, or five or six grains of dry sulphure of potash in pills, with a glass of warm water above each pill. When the first symptoms are removed, he recommends the use of sulphureous mineral waters. From his own experience he informs us, that they have very happy effects in removing the tremors and paralytic affections, which are the usual consequences of taking arsenic, and end in consumption and death. Navier likewise approves of the use of milk, because it dissolves oxide of arsenic as well as water; but disapproves of oils, because they do not dissolve it.

C H A P. VII.

Of Molybdena, and the Molybdic Acid.

WE give the name of *molybdena* to a new semi-metal discovered by M. Hielm, which is obtained from the mineral substance known by the same name. This substance is not to be confounded with common *lead ore*, *plumbago*, or the matter of the black pencils used in drawing, which is at present known under the peculiar name of *carbure of iron*. The confounding of these matters has produced that contrariety which appears in the researches of all the chemists who have examined them from Pott to Scheele. It is to be observed, that *carbure of iron* or *plumbago* is much more common than *molybdena*, of which there are but a very few specimens in the cabinets of the curious; and that therefore the experiments of chemists, except those of Messrs Quist and Scheele, have been almost always made on the former.

It is very difficult to distinguish the one from the other

other by external appearance. Molybdena, however, feels rather more greasy than the other substance: it consists of hexagonal scaly laminæ of various sizes, and scarce adhering together. It spots the fingers, and leaves bluish or silver grey marks upon paper. When reduced to a powder,—which, however, its elasticity renders difficult to be done—the powder is bluish: it may be cut with a knife; it does not break into pieces, nor has a granulated contexture like plumbago. Scheele's process for pulverising ore of molybdena was, to throw a little sulphate of potash into a mortar together with this ore, and afterwards to wash the powder with warm water, which carried off the salt, leaving the ore pure. The analysis of this ore, effected in various ways, shows it to be a compound of sulphur with the semi-metal which we are considering: but it is very difficult to obtain the semi-metal separate. The illustrious Scheele could not reduce this semi-metal, either with black flux and coal, or with borax and coal, or with oil. Bergman informs us, that M. Hielm was more successful, and obtained so much of the semi-metal as to be able to distinguish its properties; but since that, M. Hielm has published nothing concerning the matter himself.

M. Pelletier, in his experiments concerning the reduction of the oxide of molybdena, and the nature of the molybdic acid, could never obtain a lump of molybdena; what he obtained was a friable, blackish, agglutinated matter, of a metallic lustre: through a magnifier, it appeared to consist of small, round, grey, sparkling grains, which M. Pelletier takes to be the metal, or pure molybdena. Manganese has never yet been obtained in any other form but that of small grains

grains. The following are the properties which this semi-metal has been found to possess. It is grey, and consists of small agglutinated brittle grains, which are very infusible. When heated in the air, it is converted into a white volatile oxide, which, like oxide of antimony, crystallizes by sublimation into sparkling needle prisms. * This oxide becomes acid when it is super-saturated with oxigene, forming that saline product which is so well known from Scheele's researches. The nitric acid easily calcines molybdena, converting it into a white oxide, or even into the molybdic acid. Oxide of molybdena becomes blue and sparkling when it is reduced to a metallic state. Alkalis, with the help of heat, oxidate and dissolve this semi-metal. It may be mixed with lead, copper, iron, and silver; the mixtures thus made up are granulated, greyish, and very friable. Lastly, in union with sulphur, it forms sulphure of molybdena; a compound which is entirely the same with the ore of this metal, improperly known by the name of *molybdena and potelot*. As this last is the ore on which Scheele made his experiments, and as it is from this mineral, which is much better known than the metal which it contains, that he prepared the molybdic acid, we shall examine its properties more particularly.

When native *potelot*, or sulphure of molybdena, is exposed to fire in an open vessel, it exhales sulphur, and evaporates almost totally in white smoke. When heated in a ladle with the blow-pipe, it gives out the same smoke; which is condensed into yellowish crystalline laminæ, and assumes a blue colour when brought into contact with combustible bodies. M. Pelletier, upon calcining sulphure of molybdena in a crucible, with

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another crucible covering it, obtained white sparkling needled crystals, resembling that matter which is called *silver flowers of antimony*. This sublimated oxide of molybdena possesses all the distinguishing characteristics of an acid; but this would be too tedious, and too expensive, a process for the preparation of the molybdic acid.

The saline earths and the fixed alkalis, when melted with sulphure of molybdena, dissolve both the sulphur and the metal.

Several of the acids produce remarkable alterations on this ore. The sulphuric acid, concentrated, reduces the metal to an oxide, giving out a quantity of sulphureous acid by the way of ebullition.

The muriatic acid has no power of acting on this mineral.

The acid of arsenic, when distilled with sulphure of molybdena, is robbed of its oxigene, which combines with the sulphur to form sulphureous acid, volatilizes into *orpiment* with the remaining part of the sulphur, and changes part of the molybdena into molybdic acid, leaving, however, most of it still in the metallic state. From this experiment M. Pelletier concluded, that molybdena is in the metallic state in its ore.

On distilling 30 ounces of nitric acid, diluted in water with an ounce of molybdena at 5 different times; that is, 6 ounces of the acid at a time, a great quantity of nitrous gas is disengaged, and there remains in the retort a white powder; which must be washed with a sufficient quantity of cold distilled water, in order to carry off what remains of the extraneous acid, and is soluble at that temperature: six drams and an half of pure molybdic acid remains after this edulcoration.

Scheele, to whom we owe this discovery, gives it as his opinion, that the nitric acid on this occasion seizes the phlogiston, and flies off in red vapours. It likewise burns the sulphur of the molybdena; for which reason, the water used in washing the acid of molybdena contains sulphuric acid, which may be obtained by evaporation in a concentrated state, still retaining, however, a little molybdena in solution: that substance communicates to the evaporated liquid a sparkling blue colour. My opinion is, that in this instance, and in all others in which nitric acid, being distilled on any substance, reduces it to an acid, the nitric acid is decomposed; and that the disengagement of the nitrous gas, and the formation of the sulphuric and the molybdic acids, are owing to the oxigene of the nitric acid being separated and fixed in the molybdena.

The molybdic acid obtained by the same process is in the form of a white powder; its taste faintly acid and metallic. When heated in a ladle with the blow-pipe, or in a crucible with access of air, it is volatilized in a white smoke, which condenses into needled crystals, and part of it fixes on the sides of the crucible. Even after edulcoration it retains a portion of sulphureous acid: which may, however, be completely disengaged from it by the application of a strong heat.

This acid is soluble in boiling water; Scheele dissolved a scruple of it in 20 ounces of water. The taste of this solution is singularly acid, and almost metallic: it reddens tincture of turnsole, decomposes a solution of soap, and precipitates alkaline sulphures, or *livers of sulphur*: it becomes blue, and loses its consistency when exposed to cold.

The concentrated sulphuric acid, with the help of heat,

Heat, dissolves a large proportion of the molybdic acid. This solution, when cooled, becomes thick, and assumes a beautiful blue colour. These two phenomena may be caused to disappear by heating, but they appear again when the liquor is again cooled. If this combination be exposed to an intense heat in a retort, the sulphuric acid will volatilize, leaving the molybdic acid dry in the bottom of the vessel.

The nitric has no power of acting on the molybdic acid.

The common muriatic acid dissolves a large proportion of it. This solution affords a deep blue residue when it is distilled to dryness: the residue, if urged with heat, is sublimed, and one part of the sublimate is white, the other bluish. The sublimate is liable to deliquesce, and tinges metals: the muriatic acid is oxygenated when it passes into the receiver. It is easy to conceive, that in this operation the muriatic acid deprives the molybdic of part of its oxygen; and of consequence part of the molybdic acid passes into the state of molybdena.

The molybdic acid, with the help of heat, decomposes the alkaline nitrates and muriates, by disengaging their acids, and combines with their bases to form neutral salts; the properties of which Scheele has not fully examined. This acid likewise disengages the carbonic acid from the three alkalis, and forms neutral salts with their bases.

Though Scheele does not make us acquainted with all the properties of these neutral salts, to which we give the names of *molybdates of potash, of soda, of ammoniac, &c.*; yet he takes notice of three of them, which may be used as general characteristics. He has observed, 1. That fixed alkali renders the molybdic acid

cid earth more soluble in water. 2. That the same salt hinders the molybdic acid from being volatilized by heat. 3. That molybdate of potash is precipitated by cooling in small granulated crystals; and that it may be also separated from its solvent by the sulphuric and the muriatic acids.

The molybdic acid decomposes barytic sulphate and nitrate. The barytic molybdate formed on these occasions is soluble in water.

The molybdic acid appears to decompose sulphate of potash in part; and disengages from it by a strong heat a little sulphuric acid.

The molybdic acid dissolves several metals, and assumes a blue colour, in proportion as it gives up to them a part of its oxygen. It precipitates various metallic solutions, &c.

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C H A P. VIII.

Of Tungsten, and the Tungstic Acid.

THAT mineral which the Swedes call *tungsten*, and to which several naturalists, and particularly Bergman in his *Sciagraphy*, have given the name of *ponderous stone*, *lapis ponderosus*, has been considered by Cronstedt as an iron ore, and has received from him the denomination of *ferrum calciforme, terrâ quâdun cognitâ intime mixtum*. Most of the German naturalists have reckoned it among the tin ores, under the name of *white tin crystal*, or *zinn-spath*; and in almost all cabinets of natural history it is ranked as a kind of tin.

No strict analysis of this mineral had been made before Scheele attempted it. That chemist, on examining this pretended tin ore, discovered it to consist of a peculiar acid in combination with lime. Bergman made a series of experiments on this matter with the same results. This discovery was made in the year 1781. Those two Swedish chemists were induced, from

from an examination of the properties of this mineral to think the acid which they found it to contain of a metallic nature.

Since that period, Messrs D'Elhuyar of the Royal Society of Biscay, M. Angulo of the Academy of Valladolid, and M. Crell, have repeated the Swedish chemists' experiments with the same results. From what we have already said of this natural salt and its acid, the reader will have perceived, that what the Swedes call *tungsten*, is a salt formed by the union of the tungstic acid with lime: we apply the name *tungsten* to the semi-metal which appears to be the base of the acid, calling this species of ore *tungstate of native lime*.

Messrs d'Elhuyar of the Biscayan Society, have discovered, that *wolfram*, which was formerly thought to be an ore of poor iron, is a combination of the tungstic acid with iron and manganese. They have obtained a peculiar regulus of this mineral. The wolfram which they have analyzed was from the tin-mine of Zinwald. It appears in compressed hexahædral prisms; it has the metallic lustre; its fracture is foliated; and it may be cut with a knife. It contains in the hundred weight 22 parts of black oxide of manganese, 12 of oxide of iron, 64 of tungstic acid, and 2 of quartz. Native tungstate of lime from Schleckenwelde in Bohemia contains according to those gentlemen, 68 pounds of tungstic acid and 30 of lime.

Such are the two known ores of the new semi-metal which we call *tungsten*. Messrs d'Elhuyar melted one part of wolfram with four parts of carbonate of potash; they lixiviated that mixture; the water dissolved the tungstate of potash; and, with the nitric acid, they precipitated the tungstic acid

yellow powder. This precipitate, when put into a crucible with charcoal, and urged with fire, afforded a metallic button, consisting of a number of small friable globules. The following are the properties which they observed in this new semi-metal: Its specific gravity was considerable, but never above 17.6; it appeared to be very infusible, even more so than manganese; it was insoluble in the three strongest acids, and even in the nitro-muriatic acid; it entered readily into combination with some metals, particularly with iron and silver, on the properties of which it produced a singular change: it was easily reduced to an oxide, and its oxide was yellow, but changed to blue when exposed to heat, and was insoluble in acids, but soluble in alkalis, and remained dissolved in water, when triturated with it, in imitation of an emulsion. Though some of these characteristics be analogous with those of molybdena, as Bergman and Scheele had before observed in their experiments on the molybdic acid; yet taken all together, they may be allowed to distinguish tungsten as a peculiar semi-metal. But many more experiments than have yet been made are necessary to make us fully acquainted with its properties. Those chemists who have turned their views to this object, have made many more experiments on native tungstate of lime than on the semi-metal obtained from it by Messrs d'Elhuyar. In order to give a full account of their discoveries concerning this mineral, it will be necessary for us to inquire for some time on its properties.

Native tungstate of lime is still but very scarce. It is found in the iron mines of Bitzberg, and in the tin mines of Schleckenwalde in Bohemia; and most of the white tin crystals of Sauberg, near Ehrenfriedersdorf are tungstate of lime. Besides, on assaying the white tin

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crystals preserved in cabinets, in a way which we shall describe, we find among them some specimens of this substance, which were not before suspected to be such.

Tungstate of lime suffers no sensible alteration from heat: the action of the blow-pipe makes it decrepitate, and fall into dust, but does not melt it. A blue flame gives it a faint colour; but nitre divests it of that colour.

Boiling water has no power of acting on this metallic salt in powder; and it is absolutely insoluble. The action of air, earths, the salino-terreous substances, and the caustic alkalis on this salt, has not yet been attended to.

When the sulphuric acid is heated and distilled on tungstate of lime, it passes without suffering any alteration; the residue assumes a bluish colour; when lixiviated in boiling water, it affords a little calcareous sulphate; which proves that this substance contains lime, and that the sulphuric acid decomposes but a very small part of it.

The weak nitric acid acts on this salt with the help of heat, but without producing any discernible effervescence. This acid communicates to it a yellow colour, by which it is distinguished from real tin ore, and decomposes it by abstracting the lime. About twelve parts of nitric acid in the state of common aquafortis, are required to effect the entire decomposition of one part of calcareous tungstate. Scheele, in performing this operation, applied the nitric acid, not all at once, but several different times. After observing the action of three parts of the weak nitric acid on one of this neutral salt, he poured upon it two parts of caustic ammonia.

niac; the powder which the weak nitric acid turned yellow was rendered white by the alkali: he continued to apply the acid and the alkali successively till the calcareous tungstate was entirely dissolved. From four scruples which he subjected to this process he had three grains of a residue, which appeared to him to be pure siliceous earth. On precipitating the nitric acid employed in this operation by prussiate of potash, and afterwards by potash, he obtained two grains of prussiate of iron, or Prussian blue, and fifty-three grains of chalk: the ammoniac being combined with the nitric acid afforded an acid precipitate. In this experiment the nitric acid decomposes the calcareous tungstate by seizing the lime; and the tungstic acid thus separated is attracted by the ammoniac. The ammoniacal salt formed by this last solution is decomposed by the nitric acid, which has a greater affinity with the ammoniac than the ammoniac has with the tungstic acid. This last acid being much less soluble than ammoniacal nitrate, is precipitated gradually, as it is left at liberty, in the form of a white powder. That powder must be lixiviated with cold distilled water, in order that the tungstic acid may be obtained very pure.

This acid may likewise be obtained by a different process, which Scheele employed with the same success. One part of native calcareous tungstate in powder with four parts of carbonate of potash are melted together in an iron crucible; the mass is lixiviated with twelve parts of boiling water; nitric acid is poured upon it till it cease to effervesce; it is again melted with four parts of carbonate of potash, and again lixiviated with water, and treated with nitric acid till it cease to effervesce: there now remains nothing but a little siliceous earth, all the tungstic salt being decomposed.

composed. In fact, during the fusion, the potash is united with the tungstic acid, forming with it a peculiar neutral salt; while the carbonic acid, combining with the lime, converts it into chalk. When the melted mass is lixiviated, the water dissolves the tungstate of potash, which is much more soluble than chalk, and the chalk remains alone. The nitric acid employed after the water dissolves the chalk with effervescence, without affecting that portion of the calcareous tungstate which the four former parts of the alkali have failed to decompose. At the second operation, the salt having been completely decomposed by the four former parts of carbonate of potash, the nitric acid carries off all the chalk; so that by means of the eight parts of fixed alkali and a little aquafortis successively applied, the principles of the calcareous tungstate are entirely separated; its acid is united with the potash, and its lime with the nitric acid. On precipitating the calcareous nitrate by potash, we learn what quantity of lime was contained in the calcareous tungstate submitted to the process; all that now remains to be done is, to separate the tungstic acid from the fixed alkali. To effect that, the process described in the former experiment is employed. A sufficient quantity of nitric acid is poured into the lixivium of the melted mixture of tungstate of lime with carbonate of potash: The lixivium becomes turbid, and thickens; because as the nitric acid has a greater affinity than the tungstic with the fixed alkali, the tungstic acid is precipitated in powder, while the liquor still retains the nitre in solution. The precipitate is washed with cold water; and the tungstic acid is then obtained pure in the form of a white powder, as in the

former operation. This process is even preferable to the former, as being easier, and less expensive.

The muriatic acid acts on calcareous tungstate in the same manner as the nitric acid, decomposing it with equal energy; and as it communicates to it a yellower colour, Bergman recommends the use of it, for assaying and examining this earthy salt.

The tungstic acid obtained by any one of these three processes, appears, as we have already mentioned, in the form of a white powder. When exposed to the action of the blow-pipe, it becomes yellow, brown, or black; but without melting or being volatilized. It dissolves in 20 parts of boiling water. The solution has an acid taste, and reddens tincture of turnsole.

The tungstic acid appears to form with barytes a salt which is absolutely insoluble in water; with magnesia it forms another salt scarcely soluble.

When a solution of this acid is poured into lime water, it produces a small portion of precipitate, which may be considerably increased by applying heat. Scheele thinks this precipitate to be regenerated calcareous tungstate.

The tungstic acid, when saturated with potash, affords a salt, which is precipitated in very small crystals, the form of which is not certainly known. Scheele says nothing of the combination of this acid with soda. According to him, it forms with ammoniac a salt in small needles. When this ammoniacal tungstate is exposed to heat in a retort, the ammoniac escapes, and the tungstic acid remains in a dry yellowish powder: the same salt decomposes calcareous nitrate to form tungstate of lime.

When the tungstic acid is heated with the sulphuric acid, it assumes a bluish colour; with the nitric and the muriatic acids it changes to a citron yellow: it commu-

nicates a green colour to alkaline sulphure, and precipitates it. Scheele has not determined to what causes these changes of colour are owing.

That chemist, observing that the tungstic acid is easily coloured by combustible bodies, as also that, like borax, it communicates a blue colour to vitreous fluxes, heated this acid with lintseed oil in a crucible: but he obtained no metal by this process, only the acid was blackened. Bergman, however, concludes from the gravity of this acid being so considerable, from its colouring inflammable bodies, and from its being liable to precipitation by Prussian of potash, or Prussian alkali, that it is originally of a metallic nature.

We have mentioned the process by which Messrs d'Elhuyar reduced the tungstic oxide obtained from Wolfram into metallic globules; and the metallic nature of this acid can no longer be considered as problematical.

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C H A P. IX.

Of Cobalt.

COBALT or cobolt is a semi-metal of a white colour, inclining a little to red, of a fine close grain, very brittle, and easily reducible to powder by the action of a pestle. In the hydrostatic balance, it loses about an eighth part of its weight. Its specific gravity is, according to Bergman, about 7,700. It crystallizes in bundles of needles, arranged one over another.

Cobalt has never been found in nature in a pure and native state; it is almost always in calx, and combined with arsenic or its acid, with sulphur, with iron, &c. The following are the principal species of cobalt, diversified by variety of combination, as they have been arranged by Bergman and Mongez.

1. Native cobalt united with arsenic. This is a solid, grey, ponderous ore, somewhat brilliant and granulated in its fracture: it gives fire with steel, and becomes black when exposed to fire. The nitric acid

dissolves it with effervescence; with the muriatic acid it forms a sympathetic ink.

2. Cobalt in the state of an oxide. This ore, which appears to be cobalt oxidated by acids, is commonly of a blackish grey colour, sometimes resembling lamp-black, generally friable, and pulverulent. It stains the fingers; when compact, its fracture exhibits rose-coloured spots. Sometimes it resembles the scoriae of glass; a circumstance which has led some naturalists to give it the name of *vitreous cobalt ore*. When this ore is pure it contains no arsenic; but it is often mixed with martial ochre.

3. Cobalt in combination with the acid of arsenic, *flowers of cobalt*, red, rose coloured, or coloured like *peach blossoms*. The acid of arsenic which Bergman and M. Mongez have discovered in this substance, gives it its colour. This ore is either in masses or in powder, or in a striated efflorescence or in four-sided prisms, with summits of two faces. In fire, it gradually loses its colour as the arsenic acid is disengaged.

4. Cobalt ore united with iron and the sulphuric acid; *specular cobalt ore*. It has been very improperly called *sulphureous cobalt*; for it contains no sulphur, but a little of the sulphuric acid. This ore is white or grey, very brilliant, and the richest of all cobalt ores; it generally gives fire with steel.

5. Cobalt combined with sulphur, arsenic, and iron. This mineral bears the name of *white* or *grey cobalt ore*; it is of a whitish grey colour, and crystallized in complete or truncated cubes, so as to form solid figures of fourteen, eighteen, or twenty-six facets. Its fracture is sparry and lamellated. On its surface it sometimes exhibits dendrites in leaves resembling fern: In this

state,

state it is called *knit cobalt ore*. White cobalt ore is but seldom regularly crystallized, but its character may be always distinguished by its whitish grey colour, its specific gravity which is less than that of the preceding species, and the red efflorescence which almost always appears on its surface.

In assaying cobalt ore, it is first pounded and washed, and afterwards roasted to separate the arsenic. The cobalt remains in the state of a lighter or deeper black oxide: this oxide is mixed with three parts of *black flux* and a little marine salt: it is melted in a covered crucible with the heat of a forge fire: when it is entirely melted, and the matter perfectly liquid, the crucible is then cooled; as it cools, the matter which it contains is gently stirred, in order to precipitate the semi-metal, which is accumulated in a button at the bottom of the vessel. This button sometimes consists of two metallic matters, its upper part consisting of cobalt, and the under part of bismuth: a slight blow with an hammer separates the two.

Modern mineralogists, particularly Bergman and Mr Kirwan, propose the nitric acid for assaying cobalt ores. That acid dissolves both iron and cobalt. These matters are precipitated with carbonate of soda, and the precipitated cobalt is dissolved by the acetous acid. Scheffer recommends the melting of cobalt ores with three parts of potash and five of powdered glass, as a good way of determining their colouring power.

In operations in the great way, cobalt is never obtained in the metallic form. After the cobalt ore is pounded and washed, it is next roasted in a furnace which terminates in a long horizontal flue, serving instead of chimney. In this flue the sublimated oxide of arsenic is condensed and melted into glass, which is sold in

in commerce under the improper denomination of *white arsenic*. If the ore happen to contain a little bismuth, that matter, being very fusible, falls to the bottom of the furnace, and the cobalt remains in the state of a dark grey oxide, which is called *zaffre*. The *zaffre* in commerce is never pure; it is mixed with a quantity of pulverized flint, amounting to three times its own weight. When this mixture is exposed to an intense heat, it melts into a dark blue glass, known under the name of *smalt*. This *smalt* is ground to powder in mills, and diluted in water: the first portion which subsides, being larger grained, is called *coarse azure*; the water is decanted off while it is still turbid, and affords a second precipitate; it is thus decanted for four times successively, and at each time gives a finer precipitate than before; the last precipitate is the finest of all, and is improperly called *azure of four fires*. This *azure* is used in several of the arts for communicating a blue colour to metals and glasses, &c.

The *zaffre* of commerce, when melted with three times its own weight of black flux, a little tallow, and a little marine salt, affords the semi-metal improperly known by the regulus of cobalt. It is very difficult to reduce *zaffre*: A great quantity of flux must be employed, and care must be taken to keep the crucible long enough red hot, in order that the matter may become very fluid and settle, and in order too that the scoriæ may melt into a blue glass: the cobalt is then precipitated and accumulated under the scoriæ in a metallic button.

When cobalt is exposed to fire, it does not melt till it becomes very red. This semi-metal is very difficult of fusion, and appears very fixed in the fire: it is not known even whether it would be possible to volatilize

it in close vessels; but we know, that when suffered to cool slowly, it crystallizes into needled prisms, disposed one over another, and bundled together: as M. Mongez has observed, they bear a pretty exact resemblance to a mass of basalt crumbled down into pieces. All that is necessary in order to succeed in effecting this crystallization is, to melt a quantity of cobalt in a crucible till it suffer a kind of ebullition, and then, taking the vessel out of the fire, to set it upon one side, as soon as the surface of the semi-metal which it contains becomes fixed. This inclination of the vessel causes that part of the metal which is still in a state of fusion to run off, while that which adheres to the sides of the vessel in a kind of gæode, formed by the cooling of the surfaces of the cobalt, is fringed with prismatic crystals piled together.

When melted cobalt is exposed to the air, it is in a short time covered over with a dark and dusky pellicle, which is nothing but an oxide of this semi-metal, formed by its combination with the oxigene of the atmosphere. When a large quantity of oxide of cobalt is wanted, it may be produced more readily by reducing the semi-metal to a powder, and exposing it in a shallow vessel under the muffle of a cupelling furnace, stirring it constantly to change the surfaces. This powder, after being kept red hot for some time, loses its brilliancy, gains an increase of weight, and becomes black. The utmost force of fire is requisite to melt this black oxide of cobalt into a deep blue glass.

Cobalt is tarnished a little in the air, but suffers no injury from the attacks of water. This semi-metal does not combine with earths, but its oxide unites with them by fusion to form a very fine blue glass, which no intensity of fire can render volatile. This property
of

of oxide of cobalt renders that substance very useful in painting enamels, porcelain, and pottery.

We know not well in what manner barytes, magnesia, and lime act upon cobalt. Alkali dissolved in water produces an evident alteration upon it; but the alterations which it suffers from the several alkalis have not yet been sufficiently attended to.

All the acids dissolve this semi-metal, but with various phenomena, according to the state of the semi-metal and the state of the acid.

The sulphuric acid must be concentrated and boiling to dissolve cobalt. This solution is effected in a glass phial or a retort. When the acid is almost totally evaporated into sulphureous gas, the residue is washed; one part of it dissolves in the water, communicating to it a rose or a greenish colour; this is sulphate of cobalt: the residue is cobalt oxidated by the acid, the oxigene of which has entered into combination with the semi-metal. M. Baumé asserts, that when the sulphuric solution of cobalt is sufficiently evaporated and cooled, it affords two sorts of crystals; the one sort small, white, cubic crystals; the other species, square greenish crystals, six lines in length, and four in breadth. The last of these he takes to be sulphate of cobalt: the former owe their formation to some other metallic matters in union with the cobalt. The crystals of sulphate of cobalt which are most frequently obtained in the form of small needles, and which M. Sage describes as rhomboidal, tetrahædral prisms, terminating in a dihædral summit, with rhombic faces, are liable to decomposition by fire; the residue is oxide of cobalt not reducible by itself. Barytes, magnesia, lime, and the three alkalis, likewise decompose this salt, and precipitate the cobalt in a rose-coloured oxide: 100 grains

of cobalt dissolved in sulphuric acid, afford, when precipitated by pure soda, about 140 grains of a precipitate; and when precipitated by carbonate of soda, 160 grains. This increase of weight is owing to the combination of the oxigene of the sulphuric acid with the cobalt; in the second instance, the carbonic acid combining with the oxide of cobalt likewise contributes to the increase of its weight. The sulphuric acid, diluted in water, acts on zaffre, and dissolving part of it, forms with it sulphate of cobalt.

The nitric acid dissolves cobalt with effervescence, with the help of a moderate heat: as the oxygenous principle of the acid unites with the cobalt, a quantity of nitrous gas is disengaged. When the solution is saturated, its colour is a rose brown or a bright green: when evaporated by a strong heat, it affords nitrate of cobalt in small bundled needles. This salt is very liable to deliquiate: On coals it boils, but does not decompose, and leaves a deep red oxide. It is decomposed by the same saline intermediates which decompose sulphate of cobalt. If, on these occasions, more alkali be added than what is necessary to precipitate the oxide of cobalt, this last substance is then entirely dissolved, and the precipitate disappears.

The muriatic acid does not dissolve cobalt when cold, but with the assistance of heat it dissolves a certain portion of it. This acid acts with more vigour on the oxide of the semi-metal, forming a reddish brown solution, which, when heated, becomes green. When this solution is evaporated and highly concentrated, it affords muriate of cobalt, which crystallizes in small needles, and is very liable to deliquiate. Heat communicates to it at the first a green colour, and afterwards decomposes it.

Aqua

Aqua regia, or the nitro-muriatic acid, dissolves cobalt somewhat easier than the pure muriatic acid, but not with such energy as the nitric acid. This solution has been long known by the name of *sympathetic ink*, and is not visible till it be heated. Writing performed with this ink, though invisible when cold, appears when heated of a beautiful sea-green colour, but disappears again when the paper becomes cold. This property belongs to the solution of oxide of cobalt in the muriatic acid. The nitric acid, which is part of the composition of aqua regia, serves no other purpose but that of helping to dissolve the cobalt, and to maintain it in solution. The green colour which cobalt ink displays when heated, and loses again when it becomes cold, was thought to be owing to a metallic salt which was crystallized by heat, but when exposed to the cold air, attracted so much moisture as dissolved it, and made it disappear: but it has since been shown, that a solution of muriate of cobalt in water, assumes same colour when exposed to a certain degree of heat.

The boracic acid does not dissolve cobalt without an intermedium; but when a solution of borate of soda is mixed with a solution of this semi-metal in any one of the before-mentioned acids, a double decomposition is effected; the soda combines with the acid in which the metallic oxide was dissolved, and the boracic acid combining with that oxide forms an almost insoluble neutral salt, which is precipitated: on separating the supernatant liquor by a filter, the borate of cobalt is obtained separate.

Scarce any of the neutral salts are liable to be affected by the action of cobalt. When exposed to fire with nitre, it is reduced to an oxide. Put into a red hot crucible a mixture consisting of one part of cobalt with two or three of nitre well dried, no detonation will take

place.

place; but several small scintillations sufficiently discernible will be seen to follow; in consequence of which, part of the cobalt will be found changed into an oxide of a lighter or deeper red, and often of a greenish colour.

This experiment, and all the rest which have been made on the reciprocal action of nitre and metallic matters, require to be carried farther. Cobalt does not decompose ammoniacal muriate. Bucquet performed this experiment with the greatest care, but did not obtain a particle of ammoniac. This must depend on the muriatic acid having so little power of action on this semi-metal.

We know not in what manner hydrogenous gas acts upon cobalt. Sulphur combines with this substance, but not without great difficulty; but the alkaline sulphures render this combination easier. The product is an artificial ore, with facets of various sizes, or of a finer or a coarser grain, and of a white or a yellowish colour, according as the proportion of the sulphur is greater or less. M. Baumé, who has given an excellent account of this combination in his *Theory and Practice of Chemistry* (*vol. 2. page 288 to 297*), observes, that it may be decomposed by the acids, and that fire is not capable of separating all the sulphur.

Cobalt in its metallic state is of no use; but its oxide is used to give a blue colour to glass, enamel, pottery, and porcelain. It is also used for making sympathetic ink.

CHAP. X.

Of Bismuth.

BISMUTH, formerly named *tin glass*, is a semi-metal of a yellowish white colour, very ponderous, and disposed in large plates. It yields a little to the hammer like an elastic body, but soon breaks into small spangles, and is at last reduced to powder. In water it loses one tenth part of its weight. It crystallizes into polygon prisms, which are disposed in quadrangular solids, resembling the volutes of Grecian architecture or perfectly the same with those of muriate of soda. It has scarce any taste or smell.

In nature, bismuth is generally found in a metallic form. The properties by which it is known are, a sparkling yellowish colour, such a degree of softness as renders it liable to be cut with a knife, a lamellated form, and a strong tendency to fusion. It is usually crystallized in triangular plates arranged one above another. I have in my possession some specimens of this semi-metal, in which its crystals are very regular octa-

hedrons. Its gangue is commonly quartzose. It is found at Scala in Neritia, in Dalecarlia, and at Schneeberg in Germany.

A number of modern mineralogists doubt the existence of arsenical ore of bismuth: Some, however, assert it to be *chatoyant*, and generally arranged in small, glittering, light grey laminae: They tell us also, that it is almost always mixed with native bismuth and consists: the reddish efflorescence of the last of which substances is sometimes observable on the surfaces of specimens of bismuth.

Sulphureous ore of bismuth, or native sulphure of bismuth, which is taken notice of by mineralogists, is of a whitish grey colour, sometimes inclining to blue, with facets or needled prisms. The lustre and colour of this ore are the same with those of lead ore or galena: it has almost always square facets; but it has never been observed in real cubic fragments: it may be cut with a knife: it is very rare, but found at Bastnaes in Sweden, and at Schneeberg in Saxony.

Cronstedt speaks likewise of an ore of martial bismuth, which he says is found in cuneiform scales at Mosberg in Norway.

Lastly, bismuth is sometimes found in the state of an oxide. It is then in the form of a granulated efflorescence, and of a greenish, but never of a red colour, on the surface of bismuth ore. Mr Kirwan thinks this oxide to be bismuth combined with the carbonic acid. Some mineralogists assert, that there is a sulphate of native bismuth mixed with this calx.

The process for assaying bismuth ore consists in melting it in a crucible by a moderate heat, with the help of a certain quantity of reducing flux. As bismuth is

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volatile,

volatile, it must be melted as quickly as possible; nay, the best way of performing this operation is in close vessels, as Cramer recommends.

It is equally easy to melt bismuth ore in the great way. Dig a pit in the earth; cover it with billets of wood; set fire to the wood, and throw the ore, previously broken, upon it while burning; the bismuth melts and runs into the pit, where it is moulded into an orbicular cake. In some places the trunk of a pine is laid on one side and hollowed, then covered with wood; the wood is kindled, and the bismuth thrown upon it while it burns. The semi-metal then melts and runs through the pine into a cavity in the earth. The liquid bismuth is drawn from this reservoir, and poured into iron or ingot moulds.

Bismuth suffers no alteration from the contact of light: it is extremely fusible, and melts long before becoming red hot. When heated in close vessels it is entirely sublimated: If left to cool slowly, it crystallizes in Greek volutes. It is one of those metallic substances which crystallize most readily. M. Brongniart was the first chemist who succeeded in crystallizing it.

If bismuth be held in fusion, in contact with air, its surface is soon covered with a pellicle, which changes into a greenish grey or brown oxide, called *cinder* or *calx of bismuth*. By calcining nineteen drachms of bismuth in a glass capsule, M. Baumé obtained twenty drachms thirty-four grains of oxide. When bismuth is made red hot, it burns with a faint and scarcely discernible blue flame. Its oxide evaporates in the form of a yellowish smoke, which, on coming into contact with cold bodies, is condensed into a dust of the same colour, improperly called *flowers of bismuth*. What makes this dust volatilize, is the rapidity with which bismuth

burns

burns; for if it be exposed by itself to fire, it does not sublimate, but melts into a greenish glass. Geoffroy, the son, observed, that towards the end of the operation this sublimated oxide of bismuth is of a beautiful yellow orpiment colour.

The grey or brown, sublimated or vitreous oxides, are combinations of this semi-metal with oxigene, or the base of vital air. They cannot be reduced without the addition of a third matter, because the mutual affinity between the two principles of which they are composed is very considerable. But hydrogenous gas, charcoal, and all organic combustible matters which contain both of these bodies, decompose that oxide, and reduce it to a metal by attracting its oxigene, with which they have a greater affinity than bismuth has.

M. d'Arcet having exposed bismuth in a bowl of unburnt porcelain to the heat of a furnace for burning that substance, the semi-metal ran through a crevice in the crucible, leaving in the vessel a glass of a dirty violet colour, though the bismuth that ran out of the bowl was yellowish. From this fact, and others of the same kind, it appears, that there is a difference between metallic glasses formed in the air, and glasses of the same matter which have not been exposed to air during their formation.

When bismuth is exposed to the air, it is somewhat tarnished, and a little whitish rust is formed on its surface. It suffers no injury from the attacks of water, nor does it combine with earths; but its oxide combines with all earthy matters, promoting their fusion. It communicates a greenish yellow tincture to those glasses, into the composition of which it enters.

We know not in what manner the salino-terreous substances and the alkalis act upon this semi-metal.

Bismuth produces an alteration on the concentrated and boiling sulphuric acid, decomposing it in part, and causing it to exhale sulphureous gas. The mass remaining in the vessel after the decomposition of part of the acid is white. What is in a saline state may be separated by water from that which is pure oxide, and contains scarce any acid. The lixivium on being evaporated affords sulphate of bismuth in small deliquescent needles. This salt may be decomposed by fire, by the saline-terreous substances, by the alkalis, and even by water applied in a large enough quantity.

The nitric acid dissolves bismuth with amazing rapidity, or rather the semi-metal decomposes the acid by robbing it very quickly of part of its oxygen. The mixture becomes very hot, and exhales very thick red vapours. If this combination be effected in a pneumatic-chemical machine, a great deal of nitrous gas is obtained; and this is a very speedy and convenient way of obtaining that gas. During the solution, a black powder is precipitated, which Lemery took for bitumen, but Pott thinks to be oxide of bismuth very much calcined. M. Baumé thinks it sulphur; it is possibly charcoal. The nitric solution of bismuth is colourless: when highly saturated, it deposits crystals without evaporation. Evaporation and cooling give a nitrate of bismuth, concerning the form of which chemists are not agreed. M. Baumé says, that this salt is in large needles pointed at one end. M. Sage describes its crystals as tetrahedral prisms, a little compressed, and terminating in two obtuse trihedral pyramids, the sides of which are a rhombus and two trapezia. By a slow evaporation I have obtained it in very large flattened rhomboids, perfectly similar to the calcareous spar of Iceland.

Nitrate of bismuth detonizes with a faint noise into reddish sparks; it then melts and swells, leaving a

greenish yellow oxide, which cannot be reduced without the addition of some other substance. When this salt is exposed to the air, it loses its transparency, and the water of its crystals escapes. When an attempt is made to dissolve it in water, it becomes white and milky, giving a precipitate of oxide of bismuth.

The same thing happens when the nitric solution of bismuth is poured into water. Most part of the oxide of this semi-metal is then precipitated in the form of a white powder called *white paint* or *magistery of bismuth*. A solution of 100 grains of this metal in the nitric acid affords 113 grains of precipitated oxide, the increase of weight being owing to the oxigene absorbed. To obtain this precipitate very white and fine, a great quantity of water must be used in the preparation of it. The ladies use it for whitening the skin; but it unfortunately blackens it when it comes into contact with any odorous combustible matter; nay, scarce any other metallic matter possesses this property in so high a degree. Though the nitrate of bismuth be mostly decomposed by the water, yet there still remains a portion of it in solution, which cannot be precipitated by any other matter but lime or the alkalis. All solutions of bismuth may be in like manner precipitated by water. We are still strangers to the nature of nitrite of bismuth.

The muriatic acid acts with some difficulty on this semi-metal: it must be concentrated and digested for a long time over the bismuth in order to produce any effect upon it. But this solution succeeds better when a great quantity of the muriatic acid is distilled on the metal: a foetid odour exhales from this mixture; the residue is to be washed with water, which carries off a

part of the metallic oxide combined with the acid. Muriate of bismuth crystallizes with difficulty: it may be caused to sublime, and it then forms a kind of soft fusible salt, improperly called *butter of bismuth*, which powerfully attracts moisture from the atmosphere. Water decomposes it, causing it to precipitate a white oxide.

We know not in what manner the other mineral acids act upon bismuth.

Common nitre calcines bismuth, but without any sensible detonation. This semi-metal does not at all decompose ammoniacal muriate; but its oxide separates completely the ammoniac. In this operation a great quantity of ammoniac gas is obtained, and the residue is a combination of the metallic oxide with the muriatic acid. As bismuth acts not on ammoniacal muriate, on account of the muriatic acid having so little power of action on this semi-metal, it is very remarkable that its oxide should possess such a property; and the fact may be considered as a proof that this substance is in its nature not very different from saline substances.

Hydrogenous gas alters the colour of bismuth, giving it a violet tinge.

Sulphur combines with this semi-metal by fusion. From this combination there results a sort of bluish grey sparkling ore, which crystallizes into beautiful tetrahedral needles, in their colours resembling pieces of the most beautiful antimony.

Bismuth is used by workers in tin, to communicate a proper hardness to that metal. It may be employed instead of lead for the cupellation of the perfect metals; because like lead it melts into a glass, which is absorbed by the cupels. Geoffroy the younger observed a strong relation to subsist between this semi-metal and lead.

lead. We can only guess at the effects of bismuth on the animal œconomy. It is thought, with great appearance of probability, that like those of lead they might be dangerous. This semi-metal is even known to produce some unfavourable effects when applied externally.

Oxide of bismuth is used under the name of *white paint*, for whitening the skin; but the person who uses it must be careful to avoid all strong smelling matters, particularly such as are foetid. The vicinity of slaughter-houses, privies, common sewers, and almost any strong smelling matter, has such an influence on this oxide that it turns it black. The vapour of alkaline sulphures, or of eggs, acts with great energy in producing the same effect. A very common experiment in natural philosophy fully proves this fact:—A few characters are written on the first leaf of a clean paper book, containing an hundred pages; the last leaf is impregnated with a little liquid alkaline sulphure; in a few moments the hepatic vapour is conveyed by the air between the intermediate leaves to the opposite side of the book, where it communicates a deep brown colour to the characters which were traced on the first page. It has been said, that the sulphurated or hydrogenous gas penetrates through the paper: but M. Monge has proved, that it is the air which carries it from leaf to leaf; for when the leaves are glued together the phenomenon does not take place.

C H A P. XI.

Of Nickel.

CRONSTEDT, who considered nickel as a peculiar semi-metal, first made it known to the world in the Acts of the Academy of Stockholm for the years 1751 and 1754. According to him, this semi-metal is of a sparkling colour, inclining to red, especially on its outside. It is very brittle, and its fracture shows it to consist of facets, by which it may be distinguished from cobalt. M. Arvidsson, who, in conjunction with Bergman, published a thesis on the properties of nickel, which has been translated, and inserted in the *Journal de Physique* for October 1776, observes, that nickel obtained by the roasting and fusion of its ores, as Cronstedt directed, is so far from being pure, that it contains sulphur, arsenic, cobalt, and iron. As Bergman, by a number of ingenious processes, separated most of these extraneous matters, and obtained a species of nickel, differing in many of its properties from that described

by Cronstedt, we shall speak of it as the pure metal, after giving the history of its ores.

Nickel is found in combination with sulphur and arsenic. Its ores are red-coloured like copper: they are almost always covered with a greenish grey efflorescence: the Germans call it *kupfer nickel*, or *false copper*. That mineral abounds at Freyberg in Saxony; and is generally mixed with grey cobalt ore; but its red colour and greenish efflorescence distinguish it from this ore, which is grey or black, with a red efflorescence: its crystals are often cubic. Wallerius calls *kupfer-nickel*, cobalt ore of a red copper colour: he thinks it to be a compound of cobalt with iron and arsenic. Linnæus takes it to be copper mineralized by arsenic. M. Romé de Lille follows Wallerius in ranking it among cobalt ores, and considers it as an alloyed cobalt. M. Sage, on treating this ore with ammoniacal muriate, obtained from it iron, copper, and cobalt. He thinks it to be a mixture of these three metallic matters with arsenic. A little gold is also found in it according to this chemist. It is proper to observe, that the results of this gentleman's experiments on it were different from those obtained by Bergman. His experiments, he tells us, were performed on the *kupfer-nickels* from Biber in Hesse and Allemont in Dauphiny.

Cronstedt asserts, that nickel may be separated from the metallic matter to which the Germans give the name of *speiss*, and which is gathered in the crucibles in which smalt is melted. M. Monnet thinks that the *speiss* manufactured at Gengenback, about fourteen leagues from Strasburgh, is genuine nickel. And as the cobalt ore used at that place in making smalt is very pure, he concludes, that the nickel is produced by the cobalt

cobalt itself, as we shall afterwards see. But M. Baumé obtained nickel from almost all the various ores of cobalt by means of alkaline sulphure. It appears, therefore, that the cobalt ore used at Gengenback, contains a portion of nickel which is imperceptible to the eye, on account of its being so intimately united with the cobalt.

In order to extract nickel from its ore, it is first slowly roasted, to drive off part of the sulphur and arsenic which it contains. It is gradually changed into a greenish oxide; and, according to Bergman and Arvidsson, the greener this oxide, so much the more nickel does it contain. It is next melted with three parts of black flux and muriate of soda; and this fused matter affords a regulus, such as that which Cronstedt has described, but which is far from being pure nickel: the scoriae are brown or blue. A number of chemists, since Mr. Arvidsson's experiments were communicated to the world, have been induced to consider this metallic substance as a natural mixture of iron, cobalt, and arsenic. As to copper, nobody but M. Sage has obtained any of it from kupfer-nickel. M. Monnet thinks that nickel is nothing but cobalt purified of its iron and arsenic. By examining the properties of this semi-metal, we will understand the facts on which these several opinions are founded. We agree with Bergman in thinking, that what has occasioned the mistakes of chemists concerning this substance, is the extreme difficulty of obtaining nickel in a state of great purity; a fact which is fully proved in the above-mentioned dissertation of M. Arvidsson. It is certain, that when refined to as pure a state as possible, it exhibits some very singular properties; and that hitherto it has neither been separated into several metallic substances by any

ysis, nor formed by the combination of those metals of which it has been thought to consist; and therefore we have the greatest reason to consider it as a peculiar semi-metal, at least till some farther experiments convince us of the contrary.

The semi-metal which we obtain by simply fusing casted kupfer-nickel, has reddish white facets, and is very brittle. It contains a great deal of arsenic, cobalt, and iron. M. Arvidsson subjected it to six successive calcinations; each of which continued from six to fourteen hours. After each of these processes, he reduced the semi-metal. He observed, that when calcined, arsenical vapours, and a white vapour not having the same smell, were exhaled from the matter in calcination. A mixture of charcoal reduced to powder facilitates the volatilization of the arsenic. The nickel, though its weight was much diminished by those six calcinations, still smelled of arsenic, and continued to be attracted by the magnet. He afterwards melted it six times with lime and borax, and calcined it a seventh time, with an addition of charcoal, till such time as it ceased to exhale arsenical vapours. This oxide was ferruginous, and clouded with green spots. When reduced, it afforded martial scorix, and a metallic button which was still attracted by the loadstone. The same processes on a variety of specimens from different countries were always attended with the same results. M. Arvidsson employed sulphur, sulphure of potash, the detonation of nitre, as well as solution in the nitric acid and ammoniac, with a view to separate the iron from nickel: but by none of these means could he effect his purpose. From these experiments he concluded it to be impossible to obtain this semi-metal in a state of perfect purity; and likewise, that the only way of

of separating the sulphur is by repeated calcination; that arsenic adheres to it more obstinately than sulphur; that even the arsenic however may be entirely extracted from it by the use of powder of charcoal and nitre; that cobalt is still more intimately combined with this semi-metal, as the nitre causes it to be taken notice of, though nothing in the appearance of the matter indicates its presence; and that it is impossible to free nickel entirely from a mixture of iron: for after being heated in all the above-mentioned ways, it sometimes attracts the loadstone more than ever. From all these facts, M. Avidsson has been induced to think that nickel is nothing but iron in a peculiar state; and he gives a comparative view of many of the properties of this metal with those of cobalt, iron, and the loadstone. And from the resemblance which prevails among these substances, he concludes the three metallic matters to be nothing but different modifications of iron. But what seems to have chiefly contributed to make M. Arvidsson form this conclusion concerning nickel is its magnetic powers. But we cannot think it fair to confound together substances, on account merely of their agreeing in one leading property, such as this; for magnetic powers may possibly not be peculiar to iron, but common to it with other metallic substances. I am therefore of opinion, that though nickel be liable to be attracted by the loadstone; yet as purified by M. Arvidsson, it may be allowed to be a peculiar semi-metal. For, as I have already mentioned, we can neither extract from it any other metallic substance, nor imitate its composition by any mixture of metals: and besides it has properties peculiar to itself, which we are now to examine. Mr Kirwan proceeds upon the same idea of it in his Mineralogy.

It displays no facets, as Cronstedt has asserted; but its fracture is granulated: it is nine times as heavy as water: it has not that brittleness which Cronstedt ascribed to it; but, on the contrary, its ductility is so considerable, that Bergman was in doubt whether to rank it among the semi-metals or among the metals. It is a little easier to melt than iron; it is very fixed in its nature. When heated in the air, it is calcined into a green oxide; and the purer the nickel, so much the deeper is the colour of the oxide. We know not whether this oxide be fusible into a glass. It is reducible with fluxes and combustible matters, which decompose it as well as every other metallic oxide. We are equally ignorant of the effects of air and water on nickel. When its oxide is fused with vitrifiable matters in making glass, it communicates to them an hyacinth colour more or less red. The manner in which lime, magnesia, and the three pure alkalis act on nickel, is still unknown.

M. Sage says, that when four parts of concentrated sulphuric acid are distilled on one of regulus of kupfer-nickel in powder, it is converted into sulphureous acid; the residue is greyish; and when dissolved in distilled water, it becomes of a beautiful green colour. It affords foliated crystals of an emerald colour. According to M. Arvidsson, the sulphuric acid forms with oxide of nickel a green salt, in decahædral crystals; these consist of two quadrangular pyramids, joined and truncated near the base.

This oxide dissolves very readily in the nitric acid. Nitrate of nickel crystallizes, according to M. Sage, in rhomboidal cubes; all the other solutions of nickel and its oxide in the muriatic acid, or in any of the vegetable acids, are of a lighter or a deeper green. The fixed alkalis subside in a greenish white precipitate; after which they are again dissolved, and the liquor then becomes

becomes yellowish. When ammoniac is poured into a solution of nickel in nitric acid, the mixture assumes a beautiful blue colour. The same phænomenon takes place when this salt is mixed with precipitates of the semi-metal produced by the fixed alkalis. As solutions of copper exhibit the same colour with ammoniac, which colour is even considered as a sure proof of the presence of the metal wherever it appears, it has been thought, and some people are still of opinion, that nickel contains a portion of copper: Yet Cronstedt in vain attempted by every known means to obtain copper from a solution of nickel to which ammoniac had communicated a blue colour; besides, the salt dissolves copper instantaneously, but not nickel. From this circumstance Bergman concludes, that this is an original property of nickel, and not owing to copper intermixed with it. This chemist, after keeping nickel for eight days in aerated water, could not perceive any proofs of its being soluble by the carbonic acid.

Nickel detonizes with nitre. This detonation enabled M. Arvidsson to distinguish the cobalt intermixed with this semi-metal, which would otherwise have escaped his observation. After detonation, the nickel is more or less oxidated, according as a greater or a less quantity of nitre was employed on the occasion. This neutral salt likewise enables oxide of nickel to communicate a deeper hyacinth colour to glasses; and causes the glasses impregnated with that oxide to resume their colour after being deprived of it by fusion: a circumstance which happens often enough not only to oxide of nickel, but likewise to that of the semi-metal, which we are next to examine.

When oxide of nickel is melted with borax, it communicates to it also an hyacinthine colour.

It partly decomposes ammoniacal muriate. The reason of M. Sage's obtaining a ferrugineous sublimate in this experiment, must have been his having employed a regulus not so pure as that which M. Arvidsson made use of. For M. Arvidsson asserts, that the sublimate of ammoniacal muriate, produced by this metal, was white; and when tried with nut-galls, afforded no evidence of its containing iron. A little ammoniac and a little muriatic acid passes off: the residue, when reduced, proves to be nickel, which is found to have lost somewhat of its magnetic power.

We know not in what manner hydrogenous gas acts upon nickel.

This semi-metal readily combines with sulphur by fusion. It then forms a kind of hard mineral, of a yellow colour, with small sparkling facets. When exposed to a strong heat in the air, it crackles and scatters around luminous sparks, like those which fly from red iron hammered in the forge. Cronstedt, to whom we owe this fact, did not pursue the experiment far enough: Only he observed, that this phenomenon cannot take place if the mineral be covered with melted glass so as to seclude it from the contact of air; from which it appears that this effect is owing to the rapid combustion of the nickel occasioned by the sulphur. The same chemist informs us, that this semi-metal is soluble in alkaline sulphures, producing a compound similar to yellow copper ore. A series of fusions and calcinations are requisite to separate nickel from sulphur.

Nickel combines with arsenic, and adheres to it with great obstinacy. M. Monnet, who at first followed Cronstedt in thinking nickel a peculiar semi-metal, on observing that, when united with arsenic, it forms a blue glass like that of cobalt, concluded nickel to be nothing

nothing but cobalt purified from all mixture of arsenic and iron. Of consequence, M. Monnet must consider cobalt as well as nickel to be a mixture, not a peculiar metal. Bergman thinks the reason of nickel affording a blue colour with the help of arsenic to be, that the cobalt, of which nickel always contains a portion, tho' the nickel be so predominant in the mixture as to render the cobalt imperceptible, is oxidated and separated by the arsenic applied, and then begins to display its properties, and more especially that one by which it is fusible into a blue glass. We have already shown, that repeated calcination with powdered charcoal is requisite to effect an entire separation between nickel and arsenic.

Nickel combines still more intimately with cobalt than with arsenic: it is exceedingly difficult to separate these two substances. Cobalt often exists in combination with nickel, without affording any indication of its presence: the only substances that can detect it by fusion are nitre, borax, and arsenic.

Cronstedt tells us, that nickel forms with bismuth a brittle scaly regulus. These two semi-metallic matters may be separated, imperfectly indeed, by solution in the nitric acid, in consequence of nitrate of bismuth possessing the property, which we have taken notice of being decomposable by water.

Nickel has not hitherto been applied to any use.

C H A P. XII.

Of Manganese.

A MINERAL of a dark grey colour, which soils the fingers, and is used in glass-works for colouring or whitening the glass, has long been known under the name of *black magnesia* or *manganese*. From its property of acting in this manner on glass, the glass-makers who use it call it *glass soap*. It was once considered by most naturalists as a poor iron ore, both on account of its colour and because its surface is generally coated with a ferruginous earth. Pott and Cronstedt, on making an accurate analysis of this substance, determined it not to be of a ferruginous nature. Cronstedt found it to contain a little tin. M. Sage reckons it a zinc ore, and thinks it to be formed by the combination of zinc and cobalt with the muriatic acid. He adds, from his own observation, that it sometimes found to contain iron or lead.

The gravity of this mineral, its property of staining glass, and that which it possesses of giving a whitish

precipitate when any alkaline prussiate is poured upon any solution of it, led Bergman to suspect, as he informs us in the last paragraph of his Dissertation on Elective Attractions, that it contained a peculiar metallic substance. His suspicions have been fully confirmed by the experiments of M. Gahn, Doctor of medicine, who was one of his pupils, and who, in conjunction with Scheele, discovered the phosphoric acid in bones. That physician was the first who obtained regulus of manganese; very probably by treating the mineral with a reducing flux. No doubt, a very intense heat must be necessary for such an operation; for I once saw M. Brongniart, a very dexterous and experienced chemist, make an ineffectual attempt to reduce this mineral to a metallic button in a furnace in which it was exposed to a very strong heat. I have been assured, that this has been effected in Paris by means of M. Morveau's flux, with which he obtained iron in a button of thoroughly melted metal. But M. de la Peyrouse is of opinion, and I cannot help agreeing with him, that the flux is of no advantage, but rather hurtful in this operation. I have tried this reduction in a very good furnace, constructed in the laboratory of the Veterinarian school at Alfort. I have never yet obtained a well-formed button; but I have obtained a considerable quantity of grains, two or three lines in diameter. I repeatedly employed fixed alkali and borax without effect. Each of the metallic grains which I obtained in my several operations was inclosed in a kind of glass or vitreous frit of a deep green colour.

On our principles, this matter is to be regarded as a peculiar semi-metal, as it cannot be analysed, and besides, it displays properties which belong to no other

er metallic substance. To render our nomenclature uniform, we shall call this substance *manganese*.

This semi-metal is at present much better known than formerly, having been so painfully examined by Bergman, Scheele, Gahn, Rinman, d'Engestroem, Ilseman, and de la Peyrouse. Whatever I shall advance concerning it, shall be founded either on the experiments of these chemists or on my own. I must first observe, that as it is so very difficult to extract the pure semi-metal from the ores of manganese, the properties of the oxide are therefore much better known than those of the pure metallic substance. Scheele, one of the most skilful chemists of the present age, appears to have been unable to reduce this substance; for he describes none of the properties which it possesses in its metallic state.

Ores of manganese are distinguished by their form, and by their colour, which is grey, brown, or black, and more or less brilliant. There are a great many varieties of this ore.

1. Ore of manganese, crystallized into tetrahædral, rhomboidal, or striated prisms, according to their length, and separate from one another.

2. Ore of manganese, crystallized in prisms bundled together.

3. Ore of manganese, crystallized in small needles, disposed in the form of stars.

4. Ore of manganese, in a black friable efflorescence; which soils the fingers like foot.

5. Velvet ore of manganese. This is an efflorescence of very small needles, of a beautiful black colour, resembling black velvet.

6. Compact shapeless ore of manganese; of a black grey colour, generally with cavities, but very ponderous.

rous. It soils the fingers, and is sometimes found to contain brilliant needles. The Perigueux stone belongs to this variety.

7. Sparry manganese, found in the iron mines of Klapperud, at Fresko in Dahlland, and described by M. Rinman.

8. Native manganese in metallic globules, found at Sem in the county of Foix by M. de la Peyrouse. That naturalist has described a great many varieties of manganese ore which he found in the same place in the *Journal de Physique* for January 1780.

Scheele discovered oxide of manganese in vegetable ashes; and he thinks it owing to this substance, that fixed alkali, when calcined, often assumes a green or blue colour. The green colour which potash takes when treated with lime, and the rose colour which have often observed in its combination with acids, are in his opinion, owing to the metallic oxide. All coals contain a small portion of it.

The fracture of pure manganese is of a sparkling white colour; its texture is granulated like that of cobalt. It is hard, and breaks into pieces, after yielding a little to the hammer. It is more difficult to melt than iron; a circumstance which made Bergmann at first conjecture it to have some relation to platinum.

When manganese is heated in the air, it is changed into an oxide, which is at first whitish, but becomes gradually blackish as it is more and more calcined. We have observed, that the small grains of manganese obtained by the process above-mentioned, are very soon altered by the contact of air; they are instantly tarnished, and assume by and by a black or violet colour.

our; soon after they fall down into a black dust resembling native oxide of manganèse.

This rapid oxidation of regulus of manganèse by the contact of air has always appeared to me a very curious and singular fact. The globules of this metal are hard, brilliant, and very refractory, and they may be long preserved in a well stopped flask, provided their surface be unbroken, and covered with a thin crust of oxide formed during the fusion of the semi-metal: but if one of these globules be broken into three or four pieces, and their fractures exposed to the air, you in a few minutes see their colour change from a white to a purple, a violet, or a rose colour; and at last almost to a brown. If these fragments be left in a phial containing a certain quantity of air, and gently shaken from time to time, at the end of a few months they will be found reduced to a powder almost entirely black. This is a kind of metallic pulverization or efflorescence, similar to that of saline or pyritous substances. It proves the existence of a strong mutual attraction between manganèse and the oxigene of the atmosphere, and the eagerness with which these two substances tend to unite.

The action of manganèse on earths and salino-terreous substances has not been examined. The oxide of this semi-metal communicates a brown or violet colour to glass; which colour is susceptible of many modifications, and may be easily destroyed by the action of combustible matters. Nitre restores this brown or violet colour by suppling the manganèse with a new quantity of oxigene. This is the reason why the masses and retorts of white glass which we use in our laboratories, in extracting vital air from nitre, always acquire a brown or violet colour. Scheele has made a

great many ingenious experiments on this colouring of glass by oxide of manganese.

We know not well in what manner the alkalis act upon manganese; but we know that the oxide of this semi-metal combines with ammoniac, and is reduced by it. Bergman observes, that a peculiar gas is disengaged on this occasion, which he thinks to be one of the principles of ammoniac, but says nothing farther concerning it. M. Berthollet has discovered that it is azotic gas, and the hydrogen of the ammoniac enters into combination with the oxygen, which it carries off from the manganese, thus reducing it to a white semi-metal. Scheele has given the name of *cameleon mineral* to a combination of potash with oxide of manganese, which in warm water takes a beautiful green, and in cold water a red colour. Oxygen and caloric seem to be the chief causes of these phenomena. Perhaps azotic acid, which I consider as the alkalifying, or *alkaligenous* principle, is disengaged from the potash in this operation, and is in part the cause of these singular modifications of colour.

The sulphuric acid is decomposed by manganese, but dissolves its oxide. This solution is coloured and loses its colour on the addition of a combustible matter such as sugar or honey; it affords a transparent sulphate of manganese, of which the crystals are parallelopipedal. This is decomposed by fire; and it then affords vitriol and air. The alkalis separate from it an oxide of manganese, which acquires a beautiful colour on being exposed to the air.

The nitric acid dissolves this semi-metal, giving at the time red vapours. Its oxide suffers no injury from the attacks of this acid, unless the acid be re-

or some combustible body, such as honey or sugar, be added. The alkalis cause these solutions to yield a white precipitate, soluble in acids; which when heated becomes black, and is more completely oxidated. Bergman thinks manganese to be one of those metallic substances which have most affinity with salts; for in his table of chemical attractions, he places it near the top of those columns which exhibit the several affinities of the acids with the various substances with which they have a tendency to combine.

The muriatic acid also dissolves manganese; and when it effects this solution cold, the semi-metal communicates to it a deep brown colour: when the solution is heated, it loses its colour. Water precipitates it, and alkalis decompose it.

We have seen, under the history of that acid, that when it is distilled on the oxide of this semi-metal, the oxide becomes black, and returns nearly to the metallic state, by giving up part of its oxygen to the muriatic acid, which goes off in the form of oxygenated muriatic acid gas. This acid has a greater affinity than the sulphuric acid with manganese; for when a sulphuric solution of the semi-metal is poured into a quantity of muriatic acid, a precipitate is formed, which Bergman, from its property of being soluble in alcohol, has decided to be muriate of manganese; as that property is known not to belong to sulphate of the same semi-metal.

The fluoric acid dissolves but very little of oxide of manganese. The best way of combining these two substances is, according to Scheele, to decompose sulphate, nitrate, or muriate of manganese by ammoniacal fluuate.

The carbonic acid dissolves a small quantity of manganese by digestion, with cold; potash, with access of air, precipitates the metallic oxide.

Scheele has examined the action of nitre, borax, and ammoniacal muriate on oxide of manganese. With the aid of heat, the oxide disengages the acid from nitre: With potash it forms a deep green mass, which is soluble in water, and communicates its own colour to the water in which it is dissolved. This green colour is owing to the iron contained in the manganese; as the iron is precipitated; the solution becomes blue. Water and acids precipitate this alkaline solution. This is Scheele's *cameleon mineral*, above mentioned.

When nitrate of potash is heated in glass vessels impregnated with manganese, it communicates to the glass a violet colour; and the more the oxide is calcined, so much the deeper is the colour which the glass acquires.

When borax is melted with oxide of manganese, it acquires a brown or violet colour.

Ammoniacal muriate gives, on being distilled with this metallic oxide, pure ammoniac; and the ammoniac is in part decomposed. Scheele, who first observed this fact, informs us, that an elastic fluid is at the same time disengaged, which he considers as one of the principles of ammoniac; but he has not determined the nature of that fluid; and M. Berthollet has since discovered, that when ammoniac is decomposed by a metallic oxide, the hydrogen, which is one of the principles of that salt, unites with the oxygen of the oxides to form water; while the azote, the other principle of the ammoniac, passes into an aeriform

or gaseous state by entering into combination with caloric.

We know not in what manner hydrogen and sulphur act upon manganese and its oxide. Even the white oxide of arsenic appears to be capable of depriving this acid of a part of its oxygen; for it discolours glasses which have been stained brown by this substance.

To these properties of manganese Bergman adds, that it can never be entirely purified from iron; and therefore this new semi-metal, like nickel, is unknown as it exists in a state of purity. Scheele, who made an accurate analysis of natural manganese, found it to contain iron, lime, barytes, and a little siliceous earth.

Oxide of manganese is employed, under the name of *black magnesia*, in glass works, both to purify white glass from yellow, green, or blue stains, and to give it a violet colour. Probably this phenomenon is owing to the action of the oxygen separated by heat, upon substances that are coloured.

Native oxide of manganese is at present employed in the preparation of the oxygenated muriatic acid, and in many other preparations.

This native oxide, when heated by itself in a pneumato-chemical machine, affords very pure vital or oxygenous gas. This is the only vital air proper for being administered to sick persons, in the cases in which vital air is considered as a remedy.

The affinity of manganese with the principle of combustion, is a fact which in many instances serves to direct the operations of modern chemists.

C H A P.

[End of Vol. II. of the Original.]

CHAP. XIII.

Of Antimony.

ANTIMONY, *stibium*, is a ponderous semi-metal of a sparkling white colour, and bearing a strong resemblance to tin or silver. It appears to consist of laminae arranged one over another, and its surface exhibits a kind of crystals in the form of stars or fern leaves. It likewise appears in trihædral pyramids, consisting of figures like hoppers, standing on their angles one above another; these hoppers appear to result from the accumulation of quadrangular or octohædral pyramids. In water this semi-metal loses one-seventh of its weight: it is easily reducible to powder. It acts in a very sensible manner on the stomach; for it is both emetic and purgative.

Native antimony is rarely to be met with: it has been discovered by M. Anthony Schwab at Sahlberg in Sweden. M. Schreiber, director of the mines of Allemont in Dauphiny, has found native antimony in those

those mines. This native antimony is in large plates, and displays all the properties of that which is extracted from ore; only it contains one or two hundredth parts of arsenic.

M. Mongez the younger has discovered a native oxide of antimony in fine white needles, intermixed with antimony, or bundled together like zeolite. He found this oxide on the native antimony of Chalanges in Dauphiny.

This semi-metal is generally combined with sulphur, and it then forms what has been improperly called antimony, but is in propriety of language an ore or sulphure of antimony. This mineral is of a blackish grey colour, in plates or needles of various sizes, friable, and either scattered about singly or joined together in some form. It is sometimes mixed with other metals; and of these most frequently with lead or iron. It abounds in Hungary and in France in the provinces of Bourbon, Auvergne, and Poitou. Naturalists have distinguished this ore into a great many varieties, according as its filaments are stellated, irregular, parallel, *chatoyant*, &c. When it is mixed with a portion of arsenic, or has been altered by the vapours of alkaline or combustible matters, it appears in needles of a deep red colour, bearing a considerable resemblance to beautiful cobalt flowers, but rather more opaque. We may now consider the several varieties of this ore.

Varieties.

1. Sulphure of antimony, crystallized in hexahædral prisms, terminating in tetrahædral pyramids, obtuse and solitary.
2. Sulphure of antimony in striæ, or consisting of large ill-shaped needles, lying together in irregular bundles.

Varieties.

3. Sulphure of antimony in stellated striae. Its needles are divergent from a common center.
4. Lamellated sulphure of antimony; it consists of plates of various sizes, resembling the lead ore known by the name of *galena*. This variety is sometimes sparkling: when it has this property it is called *specular antimony*.
5. Red sulphure of antimony. This is a granulous efflorescence on the surface of needles of antimony: it is sometimes crystallized in red prisms or needles, the colour of which varies in deepness and brightness. In this state some naturalists call sulphure of antimony *native kermes* or *native golden sulphur*.

Formerly, sulphure of antimony was not treated as an ore in order to obtain from it the semi-metal: it was only melted to separate the gangue and any other metallic matters which might adhere to it. In that operation two pots are employed; one of them in which the ore is melted, with a number of holes in its bottom; the other standing beneath it to receive the sulphure of antimony as it melts, is buried in the earth; a fire is made around the upper pot: at first a moderate heat is applied, because the ore is very fusible, but towards the end of the operation the fire is increased, in order that all the ore contained in the mineral may melt and run off. A portion of the other metals, and particularly of the iron which is mixed with this ore, runs off at the same time, and these metals form a stratum of scorixæ, on the surface of the sulphure of antimony in the inferior pot. Although the sulphure of antimony which comes from Hungary be commonly reckoned the purest, yet it is certain, that from what-

ever

ever place this mineral come, it is always sufficiently pure and proper for the purposes to which it is applied, when its needles are regularly formed, and unmixed with scoriæ. It is to be observed, however, that the sulphur and the antimony are not always combined in the same proportion in this sulphure; and of consequence it becomes necessary to examine it, whenever it is meant to be employed in the preparation of medicines, as it is much to be wished that the strength of antimonial preparations were uniformly the same.

Sulphure of antimony melts very readily, as may be observed in the process by which it is separated from its gangue. If urged with fire after being melted in open vessels, it loses its sulphur, which goes off in yellow flowers; the metallic part is also reduced with great ease to an oxide, and it then flies off in white vapours; but a moderate heat, insufficient to melt sulphure of antimony, volatilizes the sulphur by slow degrees; and the metal then combines gradually with the oxygen of the atmosphere, forming by that combination grey oxide of antimony. This operation cannot be very well effected unless the sulphure be so much divided as to expose a great deal of surface to the atmosphere: it is therefore for this purpose reduced to powder, and exposed to a slow fire on a varnished earthen pan. A gentle heat must at first be applied, on account of the mineral being so fusible; but as the operation advances and the sulphur goes off, the antimony becomes more refractory, and the fire may then be increased till it reddens the capsule containing the mineral. The operator may conclude that his work goes successfully on, when he feels no other smell but that of sulphur exhaling from the roasted mineral, and observes that it does not form into clods; but
when

When the sulphure becomes clotted, and the sulphur is decomposed as it volatilizes (which is indicated by the suffocating smell of the sulphureous acid), the heat is then too intense, and ought to be diminished.

Though sulphur appears not to be very closely combined with antimony in its ore, yet it is impossible to drive it entirely off by roasting. The grey oxide of antimony prepared by the above process always retains a pretty considerable quantity of sulphur, even though the semi-metal have been calcined till it lost its metallic properties.

When the grey oxide of antimony is, by itself, urged with fire, it melts into a glass of a reddish brown or an hyacinth colour. This glass is more or less fusible, and more or less transparent, according as the mineral from which it is formed has been more or less calcined. If they contain but a little sulphur and a great deal of oxigene, the glass which it affords is transparent and scarce fusible: this is *glass of antimony*, properly so called, or vitreous oxide of sulphurated antimony. If the oxide contain a large proportion of sulphur, and be less remote from the metallic character, it produces a glass which is more fusible and opaque; this glass is called *liver of antimony*, because it is of a dark red colour, like that of the liver of animals. When oxide of antimony has been so completely calcined that it will scarce melt, a little sulphur or sulphure of antimony cast into the crucible in which it is exposed to heat, will cause it to melt in an instant.

When grey or vitreous oxide of antimony are heated in a crucible, with an equal quantity of black flux and a little black soap or oil, they are reduced to pure antimony. The black flux serves two purposes in this operation: the alkali which it contains combines with the sulphur,

sulphur, of which fire alone could not free the oxide, and the carbonaceous matter contributes to the reduction of the metallic oxide. Antimony is thus prepared in the great way in commerce; it is then called *regulus of antimony*. The semi-metal is moulded into flat orbicular cakes, which exhibit on their surface a crystallization resembling fern leaves.

Antimony is liable to no alteration from the contact of light. It does not melt till it be red hot; and on being exposed to an intense heat in close vessels, it is entirely volatilized without suffering decomposition. If it be left to cool slowly after being melted, and the fluid part be poured off after the surface is consolidated, what remains will be found crystallized in pyramids or hoppers, as we have mentioned above.

The semi-metal, when melted in open vessels, is very quickly oxidated. A thick white smoke rises from it, and is precipitated at the surface of the melted metal, or fixes on the lid of the crucible in the form of small white needles: this is a sublimated metallic oxide which has been improperly called *silver flowers of regulus of antimony*, or *snow of antimony*. In preparing a certain quantity of this matter, a crucible is placed horizontally in a furnace, so that its rim is exactly fitted to the mouth of the furnace to which it is luted with clay. The antimony is put into this crucible: a degree of heat is applied sufficient to melt the semi-metal and raise it in smoke: the smoke is received into a second crucible covering the first; and it is there condensed into very slender, white, and brilliant needles, which appear to be four-sided prisms.

The white sublimated oxide of antimony, not only volatilizes during the burning of the semi-metal; but, when urged with fire, it is sublimated even by itself. This oxide may be likewise melted into an orange-coloured

coloured glass: this glass is paler and more transparent than that which is formed with the grey sulphurated oxide of antimony; but it is also much more difficult to melt.

Antimony suffers no alteration from combustible matters; but they decompose the oxide, restoring it to the state of a regulus. As oxide of antimony is almost always very completely oxidated or highly saturated with oxigene, it is exceedingly difficult to make it repass into the metallic state; and as it is also a very volatile substance, it becomes necessary to perform this reduction in close vessels. The white sublimated oxide appears to be soluble in water, and to have acquired by sublimation some saline properties: Rouelle was the first who made this observation on flowers of antimony. Some other metallic oxides, particularly those of arsenic, molybdena, and tungsten, become saline and acid when saturated with oxigene; and perhaps the same property may be, one day or other, discovered to belong to oxide of antimony.

Antimony is but very little altered by air; its surface is only a little tarnished. It is not soluble in water; yet some physicians suspect that it communicates to this fluid a very discernible emetic quality. White oxide of antimony, when dissolved in water, communicates to that fluid emetic properties. This power of action, together with its volatility and solubility, gives this oxide a kind of analogy with oxide of arsenic. Many mineralogists have been of opinion that the ore of antimony is never without arsenic. It is certain, that both the ore and the regulus, when reduced to powder and thrown upon coals, exhale an odour which is easily discerned to be arsenical; and when a person is for some time exposed to that vapour, he feels it to

It upon him as a cathartic and a weak poison; as I myself have several times experienced in my laboratory.

Earthy substances have no power of action on antimony: its oxide enters with ease into the composition of glasses, communicating to them an orange colour of a deeper or a more remote resemblance to the hyacinth.

We are unacquainted with the manner in which the salino-terreous substances and the alkalis act upon antimony: we know more concerning the influence of the acids on this semi-metal.

The sulphuric acid, when boiled slowly over this regulus, is itself decomposed, and oxidates a part of the semi-metal; a good deal of sulphureous gas is exhaled from it, and towards the end of the operation there is a little sulphur sublimated. The mass which remains, after the decomposition of the acid, is a compound, consisting of a good deal of metallic oxide with a small portion of the semi-metal, combined with the acid, so as to form sulphate of antimony. The saline part is separated by means of distilled water. This salt, when evaporated with a strong heat, is very deliquescent, and not susceptible of crystallization: fire easily decomposes it; pure water, the salino-terreous substances, and the alkalis, likewise separate its principles. It is very difficult to reduce oxide of antimony that has been formed and precipitated by the sulphuric acid.

The nitric acid attracts antimony with eagerness: the acid is decomposed, oxidates most of the metal, and dissolves a part of it. This solution takes place readily enough when the substances are cold:—the salt produced, after being separated by lixiviation from the part which is oxidated, gives by evaporation nitrate of antimony, which is very liable to deliquesce, and is decomposed by fire, and by the same intermedia which decompose

compose sulphate of antimony. The oxide of antimony formed by the nitric acid is very white: it is likewise one of the most refractory and the most difficult to reduce of all the metallic oxides.

The muriatic acid appears to have more difficulty than any of the other acids in acting on antimony. Yet it dissolves the semi-metal with the help of a long digestion; but does not oxidate it so much as the sulphuric and the nitric acids. I have observed, that when the acid remains for a long time over antimony in powder, it acts slowly on the semi-metal, dissolving a good quantity of it. The muriate of antimony obtained in small needles by a violent evaporation, is very liable to deliquesce. It melts in the fire; it volatilizes, and is decomposed by distilled water like the sublimated muriate of antimony, called *butter of antimony*, which we will soon have occasion to consider, and which differs but very little from this compound. M. Monnet, who has given a good description of this combination effected by a pretty intense heat, observes that there is a very considerable difference between the one which is prepared with the oxide and that made with the semi-metal; the former being of a more fixed nature, and crystallizing in laminæ, like sulphate of lime and the boracic acid. That salt is besides decomposable by water. We have had occasion to observe that in solutions of antimony by the muriatic acid effected by distillation, there is always a portion of salt which is never volatilized by the action of fire, but resembles the salt mentioned by M. Monnet. This is owing to its having been highly oxidated by the acid. This observation may be in like manner applied to almost all solutions of metals, which are found to exist in many different states, according as the metal which

they contain is more or less completely calcined or oxygenated. M. Monnet affirms as a certain and invariable fact, that 12 grains of oxide of antimony are sufficient to saturate half an ounce of common muriatic acid; the precise strength of which he does not determine. Bergman says, that the muriatic acid has a greater affinity than any of the other acids with antimony. The oxygenated muriatic acid oxidates antimony with the greatest ease.

Aqua regia, or the nitro-muriatic acid, dissolves this metal with more energy than either of the two acids of which it is made up; for the muriatic acid has in this compound acquired new activity, in consequence of being united with the oxigene separated from the nitric acid. Nitro-muriate of antimony is very deliquescent, and may be decomposed like the other saline combinations of this semi-metal.

Sulphure of antimony, or the natural combination of sulphur with the semi-metal, is generally more entirely dissolved, but less completely oxidated, by acids than the semi-metal. Sulphur appears to defend antimony in some measure from the attacks of those saline substances. The nitro-muriatic acid acts gently on this mineral: it may be advantageously employed to separate the sulphur which it precipitates in the form of a white powder. M. Baumé recommends for this operation *aqua-regia*, consisting of four parts of the nitric with one of the muriatic acid: but he has not mentioned the precise degrees of strength which the acids ought to have. When this mixed acid ceases to act on sulphure of antimony on which it has been poured, the solution is then filtrated, and the sulphur remains on the filter. By weighing this sulphur, the respective quantities of sulphur and antimony contained in the ore

lized come to be known. But it is to be observed, that this sulphur always contains a small portion of oxide of antimony; and therefore this experiment cannot be thought very accurate, at least if the oxide be not previously purified by acids from the sulphur intermixed with it.

The action of the other acids in antimony has not as yet been examined.

This semi metal decomposes many neutral salts. M. Monnet, in his Treatise on the Solution of Metals, describes an operation, showing that antimony decomposes sulphate of potash. He melted in a crucible a mixture consisting of one ounce of that salt with half an ounce of this semi-metal. The product was a yellow, vitriform mass, extremely caustic, being nothing else but antimoniated sulphure of potash. When this mass was diluted in hot water, and afterwards cooled, it afforded a reddish sulphurated oxide of antimony, or genuine *kermes*. On this occasion, according to the new doctrine, the semi-metal, by depriving the sulphuric acid of its oxigene, causes it to pass into the state of sulphur. I have made a series of experiments which prove that many other metallic substances decompose sulphuric salts, as I shall show in the following chapters.

Antimony decomposes nitrate of potash with great rapidity. If equal parts of this semi-metal and nitre in powder be thrown into a red-hot crucible, the salt gives a smart detonation, and burns the metal by means of the oxigene which it supplies. After the operation, the fixed alkaline base of the nitre and the antimony in the state of a white oxide are found in the crucible.

This oxide has received the name of *diaphoretic antimony*. We call it *oxide of antimony by nitre*. Not an

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The matter remaining in the crucible after the detonation, consists of oxide of antimony, combined in part with the fixed alkali of the nitre, and with so much of the nitre which has escaped detonation; it contains likewise a little sulphate of potash, formed by the union of the acid of the sulphur, with the fixed alkali of the nitre. This compound has been named *solvent of Retrou*, or *unwashed diaphoretic antimony*. This matter is cast into hot water, and diluted by the solution of the saline part, while the metallic oxide remains suspended in the water. The turbid water is decanted off, and the fixed white oxide suffered to subside. After passing thro' this process, the unwashed diaphoretic antimony receives the name of *washed diaphoretic antimony*. It is moulded into little balls, and then carefully dried. The saline part of the mixture remains dissolved in the supernatant water, as well as a part of the metallic oxide, still in union with the nitrated potash. If an acid be poured on this liquor, it combines with the acid, and the oxide of antimony is precipitated. This oxide is improperly called *ceruse of antimony*, or *materia perlata* of Kerkringius. The liquor that remains after the precipitation of the *materia perlata* contains a little nitre which has escaped detonation, a small portion of

fulphate of potash produced by the detonation, and the neutral salt newly formed by the combination of the acid with the alkali, by which the metallic oxide was held in solution. Though the nature of this salt varies according as one or another of the acids is employed, yet it has been called, but very improperly, *Stahl's antimoniated nitre*. It very often contains not a grain of nitre; for the sulphuric or the muriatic acid may be with equal advantage employed to precipitate the oxide of antimony. And when the oxide is properly precipitated, no part of it remains combined with the neutral salt.

Oxide of antimony obtained by nitre may be melted, as well as the before-mentioned oxides of the semi-metal, into a glass: but being very much calcined, it is no easy task to melt it. For the same reason, it is equally difficult to reduce this oxide to a metallic state, even more difficult than to reduce oxide of antimony that has been oxidated and sublimated by fire. It is not yet known whether this oxide be soluble in water and acids.

Antimony appears to be capable of decomposing muriate of soda; for if a mixture of the two substances be heated in a retort, agreeably to what has been remarked by M. Monnet, sublimated muriate of antimony passes into the receiver. He does not describe the residue.

This semi-metal, according to Bucquet, has scarcely any power of decomposing ammoniacal muriate; neither butter or sublimated muriate can be obtained by this decomposition, agreeably to what has been asserted by Juncker.

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It acts with still more energy on solutions of antimony. On my causing a quantity of that gas obtained from iron and the aqueous sulphuric acid to pass into a nitro-muriatic solution of antimony, the solution became instantly turbid, and deposited a matter of an orange yellow colour, resembling *golden sulphur*, but never resembling real *kermes*. White oxide of antimony, when exposed in the same manner to hydrogenous gas, both dry and diluted in water, suffered no alteration.

Sulphur combines readily with antimony to form an artificial ore, which is an exact imitation of native sulphure of antimony. To effect this combination, equal parts of sulphur and antimony are to be hastily melted together in a crucible; and the product is a needled mineral of a dark grey colour, which never contains so much as half its weight of sulphur, unless the two substances have been mixed together in the proportion of a part and an half of sulphur to a part of the semi-metal. I have even observed, on melting an ounce of antimony in a retort with an ounce of sulphur, the product to be ten drams of sulphure of antimony, and to contain of consequence only two drams of sulphur; while the rest of that combustible substance had so swelled by fusion as to make its way into the receiver. No more therefore than one part of sulphur is requisite to communicate to four parts of antimony the character of sulphurated ore of antimony. And in pharmacy therefore, it is very necessary to examine in what proportion the two substances are united in any quantity of this ore used in preparing medicines, in order to estimate the effects which it may produce in combination with other substances.

The alkaline sulphures, or *livers of sulphur*, entirely

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diffolve antimony, forming in consequence of the solution a yellowish matter, from which a precipitate of antimoniated sulphur may be obtained by an acid, which instantaneously communicates to it an orange colour. *Hepatic* gas, or sulphurated hydrogen, acts on solutions of this semi-metal precisely in the same manner as hydrogenous gas.

Antimony combines with arsenic and with bismuth; but these metallic mixtures have not yet been examined with sufficient care.

Such are the principal properties of this semi-metal. But it is necessary to examine in a particular manner its ore, which has improperly received the name of *antimony*. As this mineral is most commonly used, and in a great many very valuable pharmaceutical preparations, it is natural to think that its properties must be much better known than those of the semi-metal which it contains. The alchemists, who paid much attention to this substance, were the discoverers of some part of that knowledge which we at present possess concerning its properties: And indeed no substance has undergone more experiments than have been on sulphure of antimony. We have already seen, that with the help of heat, a portion of sulphur may be separated from it; and that from this operation there results a grey oxide, fusible into *glass* or *liver* of antimony, according as the calcination is more or less completely effected. But roasting and combustion by nitre are not the only means of separating from antimony the sulphur which it contains. This separation may be likewise effected by presenting to the mineral some substance having a greater affinity with the metal than the metal has with the sulphur, or having a greater affinity with the sulphur than it has with the metal.

We have an instance of the first of these decompositions when acids are applied to crude sulphure of antimony. Those salts, especially the nitro-muriatic acid, dissolve the semi-metal, and separate the sulphur, causing it to swim on the surface of the solution. The metal even appears to dissolve easier and more completely in sulphure of antimony than when it is pure; as we have already remarked. Iron and some other metallic substances attract the sulphur from this regulus.

Nitre is successfully employed with this sulphure in the preparation of a number of medicines of some consequence. We have already seen, that when one part of this ore is made to detonize with three parts of nitre, both the sulphur and the metal are burnt, and what remains is a white metallic oxide mixed with alkali. When equal parts of nitre and sulphure of antimony are caused to detonize together, the detonation is less brisk, on account of the proportion of the nitre being less. This mixture therefore requires to be poured by spoonfuls into a red-hot crucible; whereas that which is intended to form white oxide, or *diaphoretic antimony*, needs only to be kindled once, when it immediately detonates, till the whole be reduced to a white mass. When the detonation of this mixture, consisting of equal parts of nitre and sulphure of antimony is effected, the whole mass is urged with heat till it melt; and instead of *diaphoretic antimony*, the crucible is found to contain an opaque brown mass, sparkling, extremely brittle,—in a word, a brown opaque *glass of antimony* covered with scorix. It is easy to observe, that in this operation, the quantity of the nitre is not sufficient to burn all the sulphur. That portion of the sulphur which escapes combustion, causes the

the oxide of antimony to melt together with itself. When this mixture is not urged with fire till it be brought into a state of fusion, the product obtained is nothing but a vitreous scoria, which was formerly called *Rulland's false liver of antimony*. This matter, when reduced to powder and washed in water, forms *crocus metallorum*; which is nothing but vitreous oxide of antimony pulverized, and separated from the saline matters, with which it is mixed in consequence of the detonation of the nitre.

There are two other preparations similar to the foregoing, and, as well as it, true sulphurated glasses of antimony. The one is the ruby of antimony or *magnesia opalina*; which is obtained by melting in a crucible equal parts of decrepitated muriate of soda, nitre, and sulphure of antimony. The melting of this mixture, which is not preceded by detonation, affords a vitreous mass of a light brown colour, very brilliant, and covered over with white scoriæ. The other very improperly called *medicinal regulus*, is prepared by melting a mixture consisting of fifteen ounces of sulphure of antimony, twelve ounces of decrepitated muriate of soda, and three ounces of tartar. From the fusion of this mixture, there results a glistering black glass very opaque and very dense, and of which the appearance does not, in the smallest degree, resemble that of metals. These two compounds, which differ in some external properties from true *liver of antimony*, doubtless owe those properties by which they differ from it to the marine salt used in preparing them; but its effects on this mineral have not yet been exactly estimated.

To extract antimony from its ore in the small way, no more nitre must be employed but what is requisite to burn the sulphur; and some other matter which may

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promote the reduction of that part of the metal, which is reduced to an oxide during the operation, must be likewise added to the mixture. For that end, take eight ounces of sulphure of antimony in powder, six ounces of tartar, and three ounces of nitre; mix these matters well together, and put the mixture by spoonfuls into a red hot crucible: the nitre will detonize with the tartar and the sulphure of antimony, forming black flux, and the antimony will be at the same time melted. When the matter is sufficiently melted, let it be poured into an iron cone greased and made hot: let the cone be struck with a few blows while the mixture is poured in; let the whole be suffered to cool, and the regulus will be found in a pyramidal form at the bottom of this vessel. This semi-metal is covered over with reddish black scoriæ, which readily attract the moisture of the atmosphere. When the upper surface of the regulus is convex, and exhibits a regular star, it may be considered as pure. This star, which suggested to the imaginations of the alchemists the most extravagant notions, depends on the manner in which the semi-metal crystallizes as it cools. The outer edges cool first; and the fluid matter being then driven towards the centre produces this crystallization, which never takes place but on small masses of antimony; for in large cakes of this semi-metal, as the fluid matter undulates round several centres, instead of a star, the crystallization exhibits fern-leaves under different angles. Reaumur has shown that sudden cooling prevents this stellated crystallization from taking place; and that if even one side of the cone be suddenly cooled, only half a star is obtained*. The quantity of metal obtained by this process

* There is doubtless some analogy between the way in which metallic buttons crystallize on their surface and the form which they assume,

process is not equal to an half of the sulphure of antimony employed on the occasion, although the mineral generally contains more regulus than sulphur, because part of the semi-meal enters into combination with the saline matters which form the scorixæ.

These scorixæ are compound bodies, consisting of a great many principles. They are found to contain the fixed alkali of the nitre and the tartar, combined with the sulphur of the antimony in the state of alkaline sulphure. This sulphure holds in solution a portion of oxide of antimony, and is mixed with a little sulphate of potash, formed in consequence of the sulphuric acid produced by the combustion of the sulphur having combined with part of the alkali which belonged to the nitre. Lastly, these scorixæ contain likewise a carbonaceous matter which they owe to the tartar. On boiling them in a large quantity of water and filtrating the boiling liquor, this carbonaceous matter is left on the filter. This solution is clear while it remains warm, but as soon as it cools, it becomes turbid, and deposits a reddish matter, which is at present thought to be antimoniated sulphure of potash. This precipitate is called *kermes mineral* by the dry way. When the liquor ceases to deposit a precipitate, it then affords by evaporation a matter not so deep coloured as *kermes*, which is a real antimoniated sulphure of potash. It affords likewise sulphate of potash. If, instead of evaporating the liquor, you pour an acid into it, it gives a precipitate of sulphurated oxide of antimony of an orange
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flame, when by a well-conducted cooling, and by separating the fluid from the fixed part, art disposes them in separate crystals. This has engaged the Abé Mongez's attention in his researches concerning the crystallization of metals. A.

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yellow colour; which was formerly called *golden silver of antimony*, and seems to differ but little from *kermes*.

If a quantity of sulphure of antimony reduced to powder be boiled for a few moments in water containing carbonate of potash or of soda, either of these effervescent alkalis dissolves the sulphur, and forms by that means an alkaline sulphure, which holds a part of the oxide of antimony in solution: this boiling liquor is filtered; and by cooling it deposits as a precipitate that portion which it contains of *kermes* or red sulphurated oxide of antimony. When this liquor is cooled and filtered, a new precipitate of orange coloured sulphurated oxide of antimony may be obtained from it by acids. If an alkaline lixivium be boiled anew over this residue, *kermes* may be again obtained. But this *kermes* is of a paler colour than that which was at first obtained; and the oftener the operation is repeated the more does the precipitate differ in nature from genuine *kermes*. The alkali appears to dissolve more of the sulphur than of the oxide of antimony; and sulphure of antimony should not therefore be boiled oftener than once or twice in the alkali. This operation is generally called the preparation of *kermes* by the humid way.

This name was given it by a Carthusian friar, named *Simon*; doubtless, because its colour resembles that of the animal called *kermes* *, which is used in dyeing.

* The animal *kermes*, or *scarlet grain* used in dyeing, is the skin of a female insect, which fixes on the holm or ilex, and gradually increases its bulk into the form of a cap. It loses the annular form which distinguishes those animals. Under this cap are contained the eggs of the insect. The young insects issuing from the eggs pierce through the shell; and the females being without wings, fix upon the leaves of trees and die there, after being impregnated by the males who are winged. The cochineal insect is another species, in nature similar to this; as we shall show when we come to speak of the animal kingdom.

ing. Mineral kermes has been also called *Cartbusian powder*, because it was at first prepared in a laboratory belonging to that order. Glauber appears intitled to the merit of being the discoverer of this medicine; for he prepared it with sulphure of antimony and liquor of nitre fixed by coal. But he has described his process in an unintelligible language; nay almost in alchemical symbols. Lemery, who laboured much in investigating the nature and the combinations of antimony, and who has given, under a different name, a preparation similar to *kermes*, may be regarded as being properly the inventor of this composition. It was, however, offered to the world as an entirely new preparation many years after the publication of that chemist's work; and it owes its celebrity to the surprising cures which it effected when first administered by the Cartbusian friar Simon. He received it from a surgeon of the name of *Ligerie*, who was not himself the inventor of it. *Ligerie* said that he had it from M. Chastennay, the King's Lieutenant at Landau, to whom it was said to have been communicated by an apothecary who pretended to be a disciple of Glauber's. Dodart, at that time first physician to the king, applied to *Ligerie* to publish his receipt for making *kermes*; and it was accordingly communicated to the world by that surgeon in the year 1720. Lemery, the son, in the *Memoirs* of the Academy, asserted his father's right to the honour of this discovery: and with the more reason, because most apothecaries in preparing *kermes*, still follow the process of that skilful chemist.

Ligerie's process consists in boiling a pint of rain water for two hours with four ounces of liquor of nitre fixed by coals, and a pound of sulphure of antimony broken into small pieces; filtrating the boiling liquor

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boiling the same ore with three ounces of new liquor of fixed nitre diluted in a pint of rain water; and, lastly, subjecting the second residue to a third boiling, with the same lixivium as before, namely, adding to it two ounces of liquor of fixed nitre with a pint of rain water. The liquor is then filtered, and set aside till it deposit the *kermes*; it is then washed till it become insipid, dried, and after spirit of wine has been burnt over it, reduced to powder. This process is tedious, and affords but very little *kermes*; for all that is obtained is at most but two or three drams to the pound of sulphure of antimony. It is likewise very troublesome, on account of so much boiling and evaporation of water. Lastly, Three-fourths of the ore of antimony are lost in this process; because the quantity of the alkali employed is so small in proportion to that of the mineral.

M. Baumé, who follows Lemery, gives two processes for preparing in a very simple manner, and in a very short time, a great quantity of kermes, or red sulphurated oxide of antimony; the dry, and the humid way. In the first, a mixture consisting of a pound of sulphure of antimony, two pounds of very pure alkali of tartar, and an ounce of sulphur, all pulverized, is melted in a crucible. Thus melted, the mixture is poured into an iron mortar, where it is again pulverized, though not so completely, as soon as it cools: it must then be boiled in a sufficient quantity of water; and this liquor, filtered through grey paper, affords by cooling kermes of a brown red colour: it must be washed, first with cold and after that with boiling water, till it be sufficiently purified from any mixture of saline matter; it is then dried, pulverized, and passed through a silken sieve.

To prepare *kermes* in the humid way, the same chemist directs to boil a lixivium, consisting of five or six pounds of pure fixed alkali with fifteen or twenty pounds of river water: into this liquor, when boiling, cast four or five ounces of levigated sulphure of antimony; stir the mixture; and after it has boiled for a moment filtre it: this filtered liquor deposits a great deal of *kermes* by cooling; which must be washed in the same manner as that prepared by fusion. This process, according to M. Baumé, affords twelve or thirteen ounces of *kermes* to the pound of antimony. He assures us, that the *kermes* obtained by these two different ways is entirely the same.

The theory of this operation, or the nature of *kermes*, are not yet well known; tho' many eminent chemists have been engaged in the research. It is generally thought that the alkali dissolves the sulphur of the ore, and that the sulphure which is then formed dissolves the antimony. Yet the semi-metal is not entirely dissolved; for in Lemery's process by the humid way, a grey powder is precipitated during the boiling of the liquor, which melts without any addition into real antimony. The precipitation of *kermes*, by the cooling of the lixivium, which though at first reddish and transparent, gradually loses its colour as the *kermes* subsides, is another singular phenomenon. This compound is thought to be a kind of antimony supersaturated with sulphur, and when hot soluble in fixed alkali. If you make a lixivium containing precipitated *kermes*, the *kermes* will be again dissolved by heat. The lixivium, which by cooling gave a precipitate of *kermes*, contains likewise antimoniated sulphure of potash. When an acid is poured upon it, an orange matter is precipitated known by the name of *golden-sulphur of antimony*.

and much more emetic than kermes. It is thought to contain more sulphur than kermes, and less of the metallic oxide.

Geoffroy, who in the years 1734 and 1735 communicated to the Academy several Memoirs concerning kermes, made a great many experiments, with a view to accomplish an analysis of it. He considers the action of acids as the most effectual means that can be employed for that purpose: these salts are thought by him to dissolve the semi-metal, and leave the sulphur naked; and thus he thinks the proportion in which the two principles of kermes are united in it may be estimated. An ounce of kermes contains, according to Geoffroy, seventeen grains of metal, thirteen or fourteen grains of fixed alkali, with forty, or one and forty grains of sulphur. But many chemists are at present of opinion, that kermes contains not a particle of alkali. M. Baumé says, that this salt is not one of its constituent principles, and may be entirely separated from it only by washing the mass in plenty of boiling water. M. Deyeux, who has turned his inquiries to the same subject, agrees in opinion with M. Baumé. In a series of experiments performed in conjunction with the Duke of Rochefoucauld, I have had an opportunity of being fully convinced of the same truth: but one particularly worthy of notice is, that, as the circumstances of the preparation of kermes vary, it also appears to vary greatly in its nature. It may contain more or less sulphur; and it may be naturally inferred that its effects must vary, according as the proportion of its principles is varied. It appears in general, that the state of the sulphure of antimony, the various proportions in which its principles are united, and its be-

ing more or less attenuated or divided, as well as the quantity and the particular state of the alkali in point of causticity, the quantity of the water, the time during which the lixivium is boiled, with many other such circumstances, produce great variations on the nature of *kermes*. In order to obtain it always with the same strength, the proportion of the substances of which it is composed, and the circumstances in which it is prepared, should always be the same. Without entering into a very minute detail of all the phenomena which *kermes* has offered to our observation, when treated with a great many different intermedia, we shall only add, 1. That the caustic alkalis produce a singular alteration upon it, and dissolve it even when cold. 2. That the energy with which the acids act on this substance is much diversified, and that it is very difficult to determine by means of them the quantity and the state of the semi-metal, and the sulphur which enters into its composition; because the sulphur separated from *kermes* by acids carries always along with it a certain quantity of oxide of antimony.

The caustic alkalis act with much more energy than the effervescent alkalis on sulphure of antimony; the former produce more *kermes* in proportion to their quantity and the *kermes* into which they enter, is of a much deeper colour than that which owes its formation to the latter. Lime, or lime water, when digested over antimony powder, affords, even without the application of heat, at the end of a few days, a kind of *kermes* or golden sulphur, of a beautiful red colour. Ammoniac alters in the same manner. By distilling ammoniacal muriatic with sulphure of antimony, we obtain a pulverulent purple sublimate, which appears to be a kind of ammoniated sulphure, with a base of ammoniac.

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Lastly, To conclude the history of the decomposition of sulphure of antimony, a number of other metallic substances separate the sulphur from this compound, having a greater affinity with it than antimony has. Tin, iron, copper, and silver, are all of them capable of effecting this decomposition. It is only necessary to heat tin or silver with this ore till they melt. These metals unite with the sulphur, leaving the antimony in a solitary state. Iron and copper produce the same effect: these must be first melted down, and made red hot in a crucible, after which the sulphure of antimony is added to them, and soon decomposed. The mineral hastens their fusion, and the semi-metal is separated. It must be confessed, however, that the antimony obtained by these processes is never pure: it still retains a part of the metallic substances which were employed to separate the sulphur. Its form and colour always indicate this; and it is distinguished by the name of the metal with which it is alloyed.

Antimony is employed in many of the arts; more especially in casting types for printing. It was formerly used as a purge. For this end, a quantity of wine or beer was drunk, after standing over night in vessels containing this semi-metal. But as the particular temperature of the place and the state of the wine, as being more or less acid, necessarily rendered it uncertain what quantity of the metal might be at any time dissolved, this medicine has been with good reason given up, as being very little to be trusted. For the same reason, the perpetual pills are no longer used, which were little balls of this semi-metal swallowed as a purgative. The state of the digestive juices, the nature of the mucus in the primary ducts, and the differences between differ-

rent individuals in point of sensibility, rendered the effects of those pills uncertain, and frequently dangerous.

Crude sulphure of antimony, Rotrou's solvent, the oxide of antimony known by the name of *diaphoretic kermes mineral*, and golden sulphur, are the only antimonial preparations at present used in medicine. Sulphure of antimony is employed as a sudorific in cutaneous distempers. It is suspended in a linen bag in the vessels in which ptisans for these disorders are prepared. A number of physicians deny that it produces any good effects when administered in this way. It is likewise levigated and made up into pills, which are taken for the same complaints.

Rotrou's solvent, or alkaline oxide of antimony, is recommended as a very effectual remedy in disorders occasioned by the thickening of the lymph; such as scrophulous cases, and all swellings of the glands in general. A number of physicians trust but little to the effects of washed diaphoretic antimony: they think a pure oxide of antimony, entirely destitute of virtues. Yet it is to be remembered, that Rouelle, the younger, found this oxide to be sufficiently soluble, and that in consequence of its possessing this property, it must be capable of producing some effects in medicine. Besides, as we know not in what manner the gastric juices, and those of the intestines, act on metallic oxides, we must not venture to pronounce that a substance which is apparently insoluble and insipid, can have no virtues when taken inwardly. Experience proves, however, that this medicine produces scarcely any effect in the most obstinate cutaneous disorders, however long we continue to apply it. Unwashed di-

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phoretic antimony, or Rotrou's solvent, is preferable, because, on account of its containing alkali, it is much more active than the last-mentioned medicine. A medicine called *La Chevelleray's powder* is still used in such cases. It consists of diaphoretic antimony calcined seven times successively, with fresh nitre each time, and exuviated after each operation. It differs but very little from washed diaphoretic antimony; for when this semi-metal has been once well calcined, as it is when detonized with a quantity of nitre equal to three times its own weight, it is no longer susceptible of calcination; and therefore no detonation can be observed in this operation. This medicine is absolutely incapable of producing any effects when deprived of alkali.

Kermes mineral is one of the most valuable medicines that are prepared of antimony. It is incisive, and is very happily administered in pituitous affections of the stomach, the lungs, the intestines, and even of the urinary passages. It is most frequently used in cases when the breast is affected, in order to assist expectoration. It ought not to be given, however, till the inflammation be abated. It is likewise given successfully, in small doses frequently repeated, in catarrhs of the breast, the humid asthma, cutaneous disorders, swellings of the glands, &c. It is given in doses of from half a grain to two or three grains, in certain drinks or pills. Sometimes it occasions vomiting; and often occasions sweat, or a profusion of urine.

Golden sulphur, as being a violent emetic and purgative, is but little used. It was formerly administered in the same cases in which kermes is prescribed; but its effects are much more uncertain.

There are likewise several other preparations of antimony, which are very advantageously employed in medicine: But as they are made up with vegetable matters, we will speak of them on another occasion. This is among the most valuable of metallic substances in medicine; and physicians cannot study its properties with too much attention. Scarce any other metallic substance has more engaged the attention both of alchemists and chemists; and we have described a number of valuable preparations into which it enters.

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CHAP. XIV.

Of Zinc.

ZINC is a semi-metallic substance, sparkling, of a bluish white colour, and crystallized in narrow laminæ; it has neither taste nor smell. It cannot be reduced into a powder like the other semi-metals: it yields under the hammer, and may even be beat out a good deal, provided it has not been too much hammered before. We owe the knowledge of this property of zinc to M. Sage. When zinc is wanted to be very much attenuated, it must be granulated, by being poured melted into cold water, or filed down. It greases the files employed for this purpose, and fills up their teeth. Macquer says, that when it is exposed to the most intense heat which it can bear without melting, it becomes so brittle that it may be pulverised in a mortar. This property establishes a wide distinction between zinc and those metals which are rendered more ductile by the action of heat, and renders it easy for us to reduce a mass of this metal to separate particles. It may be likewise reduced to the same state by triturating it when melted, and stirring its particles to prevent their adhering together as they cool. This operation must not be performed in an iron mortar, for zinc always dissolves a portion of that metal: a marble pestle and mortar should be used for the purpose.

In water zinc loses about a seventh part of its weight. The brilliant, and in a manner regular facets, which appear in the fracture of the pigs into which zinc is made up for commerce, are a proof that this semi-metal is capable of crystallizing in a determinate manner. The Abbé Mongez succeeded in crystallizing this semi-metal. Its crystals are bundles of small quadrangular prisms, disposed in all directions, and of a blue colour, which is changeable if exposed to the air while the metal is hot.

M. Sage thinks zinc to be, next after iron, the most common of all metals. He affirms that he has found it in all martial pyrites: and M. Grignon asserts that the *cadmia* of the furnaces in which iron ores are treated, always contains a good deal of zinc.

Native zinc is very rare: most naturalists even doubt of its existence. But M. Valmont de Bomare informs us, that he has seen specimens of this substance in the mines of lapis calaminaris in the Dutchy of Limburgh, and in the mines of Goslard. It was in small pliant filaments, of a greyish colour, and very inflammable.

This metal is oftenest found in the state of oxide: it then constitutes the *lapis calaminaris*, which in point of form is subject to very many varieties. Sometimes it is in cubic, prismatic, foliated, or laminated crystals; but oftenest in irregular masses. Its colour too varies. It is sometimes white, sometimes grey or yellow, and sometimes reddish. It is a hard body, but never so very hard as to give fire with steel. It is found in pretty large quarries in the Dutchy of Limburgh, in the county of Namur, and in Nottingham and Somersetshires in England. These quarries of *lapis calaminaris*, are often found to contain marine bodies, calcareous spar, &c.; a

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circumstance which proves them to have been deposited by water. The lapis calaminaris is still called *natural* or *fossil cadmia*. Bergman, who has analyzed zinc ores in a very accurate manner, has found almost all calamines to contain siliceous and aluminous earth, and oxide of iron in various proportions: calamines contain from .04 to .30 of metal.

Zinc, in combination with sulphur, forms what is called *blende* or *false galena*. This sulphure of zinc is commonly in scales; sometimes it appears in cubic crystals, more or less truncated. As to colour, it is sometimes lead coloured, but generally black or reddish: There is also found at Ronsberg in Norway, at Gollard, and at St Marie, a yellow and transparent species of this substance. Some blendes are phosphoric when rubbed in the dark. Some of them possess this property in such a degree, that all that is necessary to make them display it, is to rub them with a tooth-pick. Blende has received the name of *sterile nigrum*; because, when melted in order that the zinc which it appears to contain might be extracted, no zinc is obtained, as the semi-metal is volatilized while it is in fusion. All blendes, when they are either rubbed or dissolved in acids, exhale a very sensible smell of liver of sulphur. Cronstedt thinks them to consist of zinc combined with sulphur by the intermedium of iron. M. Sage is of opinion, that they contain an earthy sulphure, or liver of sulphur.

Zinc is likewise found in a saline state, combined with the carbonic, or with the sulphuric acid. The first of these compounds is known by the name of *vitreous zinc ore*, or *spar of zinc*. This ore is white, grey, or bluish, and gives fire with steel: it is ponderous, sometimes crystallized, and sometimes stalactitical, or irregularly

gularly shaped. It dissolves with effervescence in acids, giving out carbonic acid. Bergman reckons every 100 grains of it to contain 65 of oxide of zinc, 28 of carbonic acid, 6 of water, and 1 of iron.

Native sulphate, or vitriol of zinc, is found in rhomboidal crystals or white stalactites. It is often crystallized, like amianthus, in silky filaments, or in fine needles: it is sometimes confounded when in this state with *feathered alum*. It is found in Italy, and in the mines of Goslar in Hartz.

We may now proceed to arrange zinc ores in the following manner, according to the several states in which the semi-metal is found.

State I. Native zinc.

1. In pliant filaments, greyish, and inflammable.

State II. Zinc in Oxide; Calamine.

Varieties.

1. Oxide of zinc, or white calamine in tetrahedral prismatic crystals, short and bundled together in a confused manner. It sometimes inclines to green.
2. Oxide of zinc, or calamine crystallized in pyramids, resembling the hog's tooth calcareous spar; its colour, white, grey, greenish, or reddish. Messrs Sage and Romé de Lille think that this calamine is produced by the decomposition of calcareous spar. It is indeed often

Varieties.

often found to be in part calcareous and hollow within.

3. Solid, and as it were worm-eaten oxide of zinc or calamine. It is furrowed, cellular, and in some manner crystallized in dendrites.
4. Solid, compact calamine or oxide of zinc; *lapis calaminaris*. That which we get from the county of Namur is always calcined. There is an order against exporting it till it have undergone that operation.
5. Oxide of zinc, or calamine in greenish or yellowish stalagmites.
6. Oxide of zinc, or calamine in a zeolite form, known by the name of *Zeolite of Friburgh*. M. Pelletier has discovered that this pretended pearl-coloured zeolite contains to 100 parts,—from 48 to 52 of siliceous earth, 36 of oxide of zinc, and from 8 to 12 of water.

State III. Zinc mineralized by sulphur: Sulphure of zinc, blende.

Varieties.

1. Bluish grey blende, or sulphure of zinc, of a metallic appearance, and in cubic or rhombic crystals.
2. Black sulphure of zinc, or blende, either in crystals, or irregularly shaped.
3. Red or reddish brown sulphure of zinc or blende.
4. Phosphoric sulphure of zinc, or blende, of a yellowish green, or a red colour.
5. Greyish

5. Greyish yellow sulphure of zinc, or blende, mixed with galena or petroleum.
6. White blende, or sulphure of zinc.
7. Waxed yellow blende, or sulphure of zinc.
8. Sulphure of zinc, or blende in a state of decomposition, its plates separated, and its brilliancy destroyed. It passes into the state of oxide of zinc, or calamine.

State IV. Saline zinc.

Varieties.

1. Carbonate of zinc, sparry zinc, or vitreous ore of zinc.
2. Sulphate of zinc, in rhomboidal crystals, in lactites, or in silky filaments.

In assaying calamine, it is generally sufficient to reduce it to powder, to mix it with coal, and to heat the mixture in a crucible covered with a red copper plate; on which the copper immediately becomes yellow, and is converted into brass. Bergman has analyzed calamine much more accurately by the humid way: he made use of the sulphuric acid in analyzing pure calamine and carbonate of zinc: the solution he found to contain both sulphate of zinc and sulphate of iron; the last he decomposed by a known weight of zinc, and afterwards precipitated it with carbonate of soda. He has determined, that 193 grains of this precipitate are equal to 100 grains of zinc; from the weight of the precipitate he deducts the weight of the zinc employed to precipitate the iron.

As most calamines are of a more compound nature than

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than this, and contain filiceous earth, aluminous earth, and chalk combined with oxide of zinc, of iron, and even of lead; Bergman first treats those ores three times successively with two parts of nitrous acid each time: on heating them till they become dry, the acid calcines the iron and renders it insoluble; the second addition of nitric acid serves to dissolve whatever is soluble; and the iron, the filiceous earth, and the aluminous earth, remain separate. The acid holds in solution the calcareous earth and the oxides of zinc and lead. The muriatic acid is employed to precipitate the oxide of lead; the sulphuric acid to separate the lime; as to the lime it is precipitated by the alkaline prussiates. Bergman takes one fifth of the weight of this precipitate to be the oxide of the zinc contained in the calamine. He has employed likewise another process, in which he distilled the sulphuric over calamine till only a dry residue remained; this residue he lixiviated in hot water: he then precipitates this lixivium with caustic ammoniac, which separates the iron and the aluminous earth, but not the oxide of zinc, which is soluble in ammoniacal sulphate.

As to the assaying of blendes, formerly they were first roasted, and then treated in the same way as calamines. M. Monnet first asserted that these ores might be very well assayed by dissolving them in aquafortis, which combines with the metallic substance and separates the sulphur. The oxide of zinc is then reduced, after being separated by distillation from the nitric acid. Bergman has made a series of experiments on these ores, no less accurate than those which he has made on calamines; and has pursued M. Monnet's concerning the assaying of them by the humid way to a much greater length. He first separates by distillation, the
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water, the arsenic, and a part of the sulphur which they contain: he next treats them with such acids as act upon them with the most force; and finishes the operation by precipitating these solutions with various re-agents.

The ores of zinc are not wrought in order to extract the semi-metal which they contain. By melting lead-ore mixed with blendes, zinc is obtained in the form of oxide; which is sublimed in the chimnies of furnaces, and there produces greyish incrustations, which are called *tuttia* or *cadmia fornacum*. Another portion is obtained in the metallic form by cooling the anterior part of the furnace. The zinc being reduced to vapour by the action of the fire, is there condensed, and falls in grains on powder of charcoal, covering a stone placed beneath in the furnace. The powder of coal preserves the semi-metal from being calcined; it is then melted anew in a crucible, and cast into pigs. This is the process by which the greatest part of the zinc which passes in commerce is obtained at Rammelsberg, either in oxide or in metal. This zinc is always combined with a portion of lead which alters its nature. That which is prepared in China, and comes to us from the Indies, under the name of *tutenag*, is much purer*; but we are unacquainted with the process by which it is prepared. M. Sage says, that the English extract zinc, in the great way, from lapis calaminaris by distillation; but the apparatus which they employ is kept a secret.

Zinc exposed to heat in close vessels melts on becoming red hot, and volatilizes without being decomposed. If suffered to cool slowly in a vessel from which

* Mr Kirwan gives the name of *tutenag* to a variety of the brittle calamine of China, of which M. Engerstrom has given an analysis in the Memoirs of Stockholm, 1775. That ore is very rich, and contains from $\frac{60}{100}$ to $\frac{90}{100}$ of zinc.

a part of the melted semi-metal may run out, the remaining part crystallizes into needled prisms. M Mongez uses for this purpose a roasting pot with several holes in its sides and bottom, which he stops with earth of bones. When the surface of the zinc cools, all the holes are gradually stopped; and the metal is stirred with a red iron introduced by one of them. This simple process causes the melted zinc to run out; and the roasting pot is then shaken till the metal cease to run, and the portion which is cool crystallize. If left in the vessel, it takes a metallic colour: if exposed to the air, it assumes the shades of the rainbow. When melted zinc is brought into contact with the air, it is covered with a grey pellicle, which is soon converted into a yellowish oxide, not very refractory, but easily reducible. This oxide weighs more than the zinc of which it is formed; but if the semi-metal be violently heated, it burns with a white or a greenish yellow flame, which is very brilliant, and resembles the flame of phosphorus. The oxide is carried up and volatilized by the current of this flame, but condenses in the air into the form of very light white flakes, which are called *flowers of zinc*, *pompholix*, *nihil album*, *philosophical wool* or *cotton*. They are a thoroughly calcined oxide of zinc; and their gravity is greater than that of the semi-metal from which they are formed: for M. Baumé obtained sixteen ounces six drachms and fifty four grains of this oxide from a pound of zinc. It is not volatile of itself; and its sublimation is owing to the rapidity with which the zinc burns; for if this oxide be exposed to fire after being volatilized, it remains fixed: it retains a phosphoric light which it displays in the dark; it melts into a glass; but a very intense heat is requisite: Vitrified oxide of zinc is of a beautiful pure yellow colour.

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The oxide and the glass of zinc are nothing but a combination of the semi-metal with oxigene, or the base of vital air. The only difference between the white oxide and the glass seems to be, that in the latter the principles are more intimately united. This compound is one of those metallic oxides which are indestructible; nor can it be reduced without the addition of another body. In order to reduce it, we must bring it into contact with some combustible substance. On exposing to an intense heat a mixture of white oxide of zinc with coal or any other combustible matter, zinc is obtained; and the coal is partly burnt by means of the oxigene, of which it robs the metallic oxide. Zinc has therefore less affinity than coal with oxigene, though it appears to be the more combustible of the two. This operation succeeds best in close vessels: and we are told, that the English reduce lapis calaminaris by distillation.

Zinc is scarce alterable by air: only its surface is a little tarnished, and it seems beginning to oxidate.

Water acts powerfully on zinc when the semi-metal begins to become red hot. It easily reduces zinc to an oxide, giving out at the time a good deal of hydrogenous gas, which shows that it is decomposed by the semi-metal, which with the help of an high temperature deprives it of its oxigene. Messrs Lavoisier and Meusnier were fully convinced of this fact by their experiments on the decomposition of water. A little carbonaceous matter from the zinc is held in solution by the hydrogenous gas obtained in this process.

Zinc has no power of action on siliceous or on aluminous earth; but its oxide enters into vitreous compounds, and communicates a yellow colour to glass.

Neither barytes, nor magnesia, nor lime, acts upon zinc.

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When liquor of caustic potash or soda is boiled over this semi-metal, it blackens its surface, and dissolves a certain quantity of oxide, which, as M. de Laffonne has shown, may be separated from it by acids. Ammoniac acts less effectually on zinc hot, on account, no doubt, of its volatility: when it is digested cold, however, over zinc, it dissolves a little of it. In the solution of zinc by the three alkalis, a certain quantity of hydrogenous gas is disengaged; the production of which is owing to the decomposition of the water: so that it is this fluid which acts on the semi-metal, reduces it to an oxide, and renders it in part soluble in alkalis.

The sulphuric acid, diluted in water, dissolves zinc cold. As the solution takes place, the semi-metal assumes a blackish grey; a considerable degree of heat is excited; and a black powder is precipitated; the nature of which was long unknown, but which is now known to be *plumbago*: a good deal of hydrogenous gas, with a little carbonaceous matter dissolved in it, is disengaged. This elastic fluid, which has the same smell as the gas obtained when iron is dissolved by the same acid, is certainly owing to the water; for the concentrated sulphuric acid never dissolves zinc without the help of heat, and the gas which it then affords is sulphureous. The water, therefore, begins with oxidating the zinc, and the acid then dissolves the oxide of the semi-metal. When hydrogenous gas is no longer disengaged, the effervescence ceases, and the smell of the solution changes, becoming perfectly the same with that of grease a little acid. The liquor is whitish and somewhat turbid: on dilution in water it becomes transparent. When evaporated it affords a white sulphate of zinc, rather more soluble in hot than in cold water; of which a solution crystallizes by cooling. This salt may be easily

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enough obtained in very regular crystals, which are used in the arts under the name of *white copperas*, *white vitriol*, *Goffard's vitriol*. On exposing to the air for a few days a solution of this salt in boiling water, a little evaporated, it affords tetrahædral prisms, terminating in pyramids having likewise four sides: the sides of these prisms are smooth. Such is the form which Messrs Sage and Romé de Lille ascribe to them, and my observations enable me to confirm what they have advanced. Bucquet observed the prisms to be rhomboidal; yet M. Monnet asserts, that it is very difficult to make this salt crystallize, and that it is obtained in regular crystals without consistency, by being violently evaporated and suddenly cooled. The white oxide of zinc likewise dissolves in the sulphuric acid, forming the neutral salt of which we are speaking.

This salt has a pretty strong styptic taste. According to Hellot, it loses a part of its acid by the action of fire. That acid possesses the characteristic properties of the sulphureous acid: it becomes hot when mixed with the concentrated sulphuric acid, as has been remarked by Macquer. After being exposed to the action of fire, this sulphate of zinc appears to be converted into sulphite of zinc; the properties of which are not well known. Sulphate of zinc, when very pure, suffers scarcely any alteration from air: in time its oxide becomes more completely calcined by absorbing more oxygen: it then becomes yellow, and not entirely soluble in water. Sulphate of zinc is decomposed by aluminous earth, barytes, magnesia, lime, and the three alkalis. The oxide of zinc precipitated by these substances may be again dissolved in acids, and even in alkalis. Ammoniac acquires, in this solution, a dirty brown colour. Sulphate of zinc decomposes nitre, and is itself decomposed by that neutral salt. By distilling this mixture

two kinds of nitrous acid are obtained, which do not mingle together, as well as glacial sulphuric acid. We will speak more particularly on this matter under the article sulphate of iron, or *martial vitriol*.

We find in commerce a sulphate of zinc under the name of *white copperas*, which is prepared in the great way at Goslard. Blende is roasted; a portion of the sulphur then burns, and affords sulphuric acid, which dissolves the oxide of zinc. The ore is next washed; and the lixivium, after being suffered to settle, is decanted off, evaporated, and thus crystallized. This salt is then melted by a moderate heat, in order to free it from the water of its crystals, and left to cool. By this process it is condensed into white, opaque, and grained masses like sugar. *Vitriol of Goslard*, when dissolved in boiling water, crystallizes by cooling; and its crystals are a little reddish. The colour is ascribed to the impurities of the salt; which is thought to contain a small portion both of lead and of iron. To purify it, a little zinc may be cast into the solution. This semi-metal precipitates the oxide of lead and iron, because it has a greater affinity with the sulphuric acid than they have. The liquor is now filtrated; and after passing through the filter, contains nothing but pure sulphate of zinc. What especially leads us to think it is the oxide of iron which often alters the *vitriol of Goslard*, is that the zinc which passes in commerce is sometimes attracted by the loadstone; a property which it must, no doubt, owe to iron. If a person were to make experiments; therefore, on this semi-metal, it would be proper to use no specimens but such as he had himself prepared by reducing precipitate of sulphate of zinc, after purifying it as we have directed. We must, however, observe, that the reason why pigs of zinc are at-

tracted by the loadstone at the part where they have been cut, is often nothing else but their having been cut with iron scissars or wedges.

The nitric acid, when weak and diluted in water, combines with zinc cold, and with great rapidity. A considerable heat is produced on this occasion, as well as when the same semi-metal is dissolved in the sulphuric acid. The lively effervescence which takes place when this combination is effected, occasions the disengagement of a great quantity of nitrous gas, which the air renders instantly red when the operation is performed in an open vessel: but by itself this gas is colourless, and it may be collected under water by immersing in to a quantity of that fluid the extremity of the vessel containing the mixture. This experiment proves that zinc decomposes the nitric acid by robbing it of a part of its oxigene. If the zinc be mixed with a little iron it is covered with a reddish ochreous powder; which is nothing but a portion of that metal thoroughly calcined by the acid: if pure, it precipitates some flakes of a black matter, or carbure of iron, in the same manner when in combination with the sulphuric acid: a much greater proportion of oxide of zinc will remain dissolved in the nitric than in the sulphuric acid. M. Baumé says, six ounces of this acid dissolve five drachms and an half of zinc in less than two hours. The nitric solution of zinc is of a greenish yellow colour, and a little turbid when new made; but after being suffered to settle for some time, it loses this colour and becomes transparent. Altho' the acid with which it is made be diluted in water; yet it is so very caustic as to corrode the skin. I obtained from this solution by evaporation and cooling crystals in compressed and striated tetrahædral prisms terminating in four-sided striated pyramids. When this nitrate of zinc is placed on burning coals, it immediately

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mediately melts and runs into separate portions, which detonate as they become dry; and the detonation is attended with a faint reddish flame. It does not, however, exhibit the same phenomenon when melted in a crucible: it cannot then be dried even by the most moderate heat without suffering some alteration. Nitrous gas escapes from it; its colour becomes a brown red, and its consistency gelatinous. If cooled when in this state, it retains its softness for some time; and if the application of heat be continued, it rises suddenly up into a yellowish oxide. Hellot obtained from nitrate of zinc by distillation a very fuming nitrous acid; and observed it to assume a red colour in melting. It may be understood, that when heat disengages nitrous gas from this salt, it passes into the state of nitrite of zinc: It affords also a certain quantity of oxygenous gas or vital air. Nitrate of zinc readily attracts the moisture of the atmosphere; on which event it loses its regularity of form. What remains of the crystals of this salt, after a few days exposure to the air, is only striated pointed prisms without any determinate form. We know not whether it be decomposable by other acids. Messrs Pott and Monnet affirm, that oxide of zinc has a strong affinity with all these salts; but does not combine with any one of them in preference to the rest. According to Hellot, oxide of zinc forms the same salt by solution in the nitric acid. If nitrous acid be employed to effect this solution, nitrite of zinc is produced; the nature of which is not exactly known.

The muriatic acid acts on zinc in as rapid a manner as the nitric acid. A considerable quantity of hydrogenous gas is disengaged during the lively effervescence with which this act of combination is accompanied: its properties are the same with those of the hydrogenous gas produced by the sulphuric acid acting upon this

semi-metal; and, as in that instance, it arises from the water decomposed by the zinc. A blackish matter is gradually deposited in flakes by the liquor; which can be nothing but a combination of carbonaceous matter with iron. The solution of zinc by the muriatic acid is colourless; nor does it afford crystals by evaporation. When heated, it assumes a blackish brown colour, exhales the acrid and pungent vapours of the muriatic acid, and becomes much thicker: it has been exposed to the air in this state for eight days without giving crystals. By distillation it affords a small portion of very fuming muriatic acid and solid fusible muriate of zinc. Messrs Hellot and Monnet have given very good descriptions of this operation. In my courses of lectures I have repeated it several times, and have obtained, first, a small portion of yellowish acid, and afterwards a congealed matter in the neck of the retort. This muriate of zinc was of a beautiful milk-white colour, very solid, and formed, like stalactites, of small radiated needles: it melts by a mild heat. I preserved some of it for a number of years in well-stopped glass flasks; it had acquired but little moisture in all that time; the parts which touched the glass were become a little yellowish, and the bottom of the glass was coloured like a rainbow. This alteration is, no doubt, the effect of light. In the retort used in the above process of distillation there remains a vitriform and deliquescent blackish matter. The muriate of zinc which Hellot obtained by distillation was yellowish; the sulphuric acid, he says, disengages the muriatic acid. We know nothing of oxigenated muriate of zinc.

The liquid carbonic acid, when zinc or oxide of zinc is put to digest in it, dissolves, according to Bergmann, a pretty considerable quantity of it in the space of twenty four hours. This solution, when exposed to the air,

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covered over with a pellicle which reflects various colours, and is actually, according to the celebrated chemist abovequoted, carbonate of zinc.

We are not as yet well acquainted with the manner in which the fluoric and the boracic acids act upon zinc.

All solutions of zinc in acids are precipitated by lime-water, magnesia, fixed alkali, and ammoniac. The oxide of this metal then appears in the form of white or yellowish flakes, according to the state of the solution and the purity of the precipitant. It may be reduced by means of zinc: it is soluble in acids and alkalis. By adding more alkali than is requisite to precipitate the oxide of zinc dissolved in an acid, the precipitate is caused to disappear gradually, and the liquor to assume a dirty yellow colour; an indication that the oxide is dissolved in the alkali. When, instead of pure or caustic alkalis, carbonate of potash, soda, or ammoniac is employed to separate zinc from acids, there is scarce any effervescence; the precipitate is whiter than in the former case, and the carbonic acid appears to unite with the oxide of zinc; so that in this case there are two decompositions and two new combinations.

Zinc decomposes a number of the neutral salts: When exposed to fire in a crucible with sulphate of potash, it decomposes that salt, and forms sulphure of potash, in the same manner as antimony. In this operation, the zinc seizes the oxigene of the sulphuric acid; and the acid passing into the state of sulphur, is then dissolved by the potash: the sulphure formed by this combination dissolves a portion of the oxide of zinc. All sulphates are equally liable to be decomposed by zinc.

When this metal is reduced to filings or powder, it makes nitre detonize with amazing rapidity. If the

mixture be made very dry, and cast by spoonfuls into a red crucible, it produces a clear red flame. So vigorous is this inflammation, that it darts the burning matter to a distance from the crucible; which renders it necessary for the operator to be very cautious. The zinc burns with the help of the oxigene of the nitre which is decomposed, and is reduced to an oxide, which is more or less complete according as a greater or a less quantity of nitre has been employed. A part of the residue is soluble in water. That part consists of potash in combination with so much of the oxide of zinc, and may be precipitated by acids. Respour ascribed to this solution the property of dissolving all metals; if we may believe Hellot, who has given it as the *alkaest* of that alchemist.

Zinc appears from Pott's experiments to be capable of decomposing muriate of soda. It acts with peculiar force in decomposing ammoniacal muriate: M. Monnet affirms, that when this salt is triturated with the semi-metal, there is ammoniac disengaged, Bucquet has observed, that when this salt is distilled with zinc, a good deal of ammoniac gas is obtained, as well as of hydrogenous gas, produced when the muriatic acid enters into combination with the semi-metal. The disengagement of the ammoniac, so easily effected, he perceived to be owing to the lively re-action of the zinc on the muriatic acid. Oxide of zinc is also disengaged on the occasion, according to Hellot. The residuum of this decomposition is muriate of zinc, which may be sublimated.

When a solution of aluminous sulphate is boiled with filings of zinc, it is decomposed, and sulphate of zinc is formed in consequence of its decomposition.

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The base of that salt therefore appears to have less affinity than zinc with the sulphuric acid. We owe this fact to Pott. We will hereafter have occasion to make a similar observation concerning several other metallic substances.

The effects of hydrogenous gas on zinc have not yet been attended to; only I have observed, that if the semi-metal be immersed into the gas, it assumes after some time a very bright changeable blue colour; but I have not pursued this alteration farther. It does not reduce the oxide of this semi-metal, which retains its oxigene with so much force as even to decompose water.

Zinc appears at first to be almost incapable of combining with sulphur. When these two substances are melted together, they melt without entering into any kind of union. Yet M. Dehne has observed, that if they be kept together in fusion for some time, the zinc is partly calcined, assumes a brown or a grey colour, and acquires an increase of weight. M. de Morveau has since discovered, that oxide of zinc combines easily with sulphur by fusion, producing by this combination a grey mineral, very like the *blende* of Huelgoet. Sometimes bright yellow prismatic needles are found sticking to the lid of the crucible in which this combination is accomplished. M. de Morveau observes, that it is the more probable that the natural *blende* is formed by the combination of oxide of zinc with sulphur, as we find no native zinc.

M. Malouin did not succeed in combining zinc with alkaline sulphure, though he attempted it both in the humid and the dry way, and with various proportions of the substances.

The same chemist combined zinc with arsenic. He has

has observed that it does not unite so well with the oxide of arsenic. However, in an experiment in which he distilled a mixture of oxide of arsenic, tallow, and zinc, he obtained a blackish mass resembling blende, but softer than that ore. It appears likewise, that when zinc and oxide of arsenic are distilled together, the former deprives the latter of a part of its oxigene; for part of the semi-metal is calcined, while part of the oxide passes into the metallic state. It would be of considerable service to chemistry to determine, by a series of experiments, the reciprocal action of metals and metallic oxides; together with the various degrees of affinity with which oxigene adheres to each of these substances.

We know not whether it be possible to combine zinc with cobalt.

It does not combine with bismuth; and when these two semi-metals are melted together, the bismuth, being the most ponderous of the two, sinks under the zinc, and they may be separated by a blow with an hammer.

When zinc is melted with antimony, it gives an hard brittle mixture, which Malouin only mentions.

Zinc is of great use in the arts. It enters into several metallic mixtures; particularly in tombac and prince's metal. Filings of zinc are mixed with powder to produce bright, sparkling artificial stars in fire-works. Several persons have proposed the use of this metal as being still more effectual than tin, for plating over the inner parts of copper vessels. Malouin, after comparing these two metallic substances, in two Memoirs, which appear among those of the Royal Academy of Sciences for the years 1743 and 1744, gives an account of some experiments which he made concerning the plating of
copper

copper vessels with zinc. The result of his researches is, that this kind of plating might be more exactly spread over the copper, and would be much harder and much less liable to melt than a plating of tin; and of consequence more lasting, and less likely to fall off the copper. Macquer acknowledges these advantages, but makes some very important observations on the use of zinc for plating kitchen utensils. He thinks it dangerous, because it is soluble in vegetable acids, such as vinegar, verjuice, &c. and is a pretty strong emetic. He proves this last fact by vitriol of zinc, which was formerly administered to excite vomiting, under the name of *gilla vitrioli*, and referring to Gaubius, who mentions a celebrated remedy for convulsive complaints, known by the name of *luna fixata Ludemanni*, as being sublimated oxide of zinc. This *luna fixata* was a strong emetic, and was administered in very small doses. But may we not presume that these observations can refer only to sulphate of zinc, and to the oxide of that semi-metal, and respect neither the semi-metal itself nor the salts which it forms by combining with vegetables? M. de la Planche, doctor in medicine of the faculty of Paris, has, by a set of experiments made with care upon himself, determined these conjectures to be not only plausible, but certainly true. He swallowed salts formed by zinc with vegetable acids, in much stronger doses than what could possibly be contained in any aliments prepared in copper vessels plated with tin, without suffering from them any bad effects. However, as too much attention cannot be paid to whatever concerns the health and lives of mankind in general, it would certainly be highly improper to form any decided opinion concerning this matter, till it be determined by a great many experiments in what manner

manner zinc and the salts which it forms with vegetable acids can affect the animal œconomy.

The German physicians employ sublimated oxide of zinc successfully as an antispasmodic in convulsions and epileptic fits. It is not much used in France. It might, however, be of some utility if given in pills, and in doses of half a grain a-day. I am told, that at Edinburgh a much more considerable dose has been given without any sensible effects. This fact contradicts what Gaubius tells of the emetic powers of zinc.

Pompholix, tuttia, &c. are used as excellent desiccatives for humours affecting the eyes, &c.

CHAP.

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CHAP. XV.

Of Mercury.

MERCURY, or quicksilver, has the opacity and brilliancy of metals; next after gold and platina, it is the most ponderous substance known. A cubic foot of mercury, if very pure, weighs nine hundred and forty-seven pounds; in water it loses one-thirteenth of its weight. As it is habitually fluid, we know nothing concerning its ductility or tenacity, and are at a loss what rank to assign it among metals. However, its excessive weight, habitual fluidity, extreme volatility, together with the singular alterations which it is liable to suffer by combination, cause it to be considered with great probability as a peculiar substance, not otherwise related to metallic matters, but by its brilliancy, gravity, and combustibility; which might therefore be with more propriety classed by itself. We give it between the semi-metals and the metals.

It was long thought that mercury could not lose its fluidity; but the academicians of Petersburg have proved

ved the contrary. Those philosophers made a number of experiments upon it during the severe cold of the year 1759, by a mixture of snow with fuming spirit of nitre; till the mercury fell in a thermometer graduated after de Lisle to 213 degrees, corresponding to 46 degrees below the freezing point in Reaumur's thermometer. Those gentlemen, observing that the mercury then ceased to sink, broke the glass in which it was contained, and found it frozen into a solid body, which might be beaten out by the hammer. From this experiment it appears that mercury is susceptible of concretion like other metallic substances; and in that state possesses a certain degree of ductility. They could not exactly estimate the ductility of mercury; for at every stroke of the hammer, some point of the metal became so hot as to melt and run.

M. Pallas, in the year 1772, succeeded in effecting the congelation of mercury at Krasnejark, by a natural cold of $55\frac{1}{2}$ degrees; and observed, that it then resembled soft tin; that it might be beaten out into thin plates; that it might be easily broken, and the fragments, when placed near each other, united of themselves. Mr Hutchins, in 1775, observed the same facts at Fort Albany; and Mr Bieker at Rotterdam in 1776, at 56 degrees below Zero. At last, in the year 1783, the congelation of mercury was effected in England by a more moderate heat; and 32 degrees under Zero, in Reaumur's thermometer, was determined to be the term at which this congelation takes place. The mercury's falling lower in former instances, is therefore to be ascribed to the contraction or condensation of the solid metal. Mercury is therefore the most fusible metal known; the most intense cold that is known in those countries in which it is native is never sufficient to render it solid. Probably,

If in the above experiments the cold which froze mercury had been gradually applied to it, it would have caused that metallic matter to assume a regular crystalline form.

The habitual fluidity of mercury has caused it to be considered as a peculiar metallic water, and it has been called *aqua non madefaciens manus*; water that does not wet the hands. It is true, mercury does not wet the hands, nor any of those bodies which are liable to be made wet by water, oil, and other liquors: but the cause of this phænomenon is, that there subsists but little affinity between this metallic fluid and those bodies. For, when mercury is brought into contact with any substance with which it can combine, such as gold, silver, tin, &c. it adheres to these bodies, and wets them to such a degree, that they cannot be dried without evaporating over a fire the mercury with which they are coated.

Mercury being a metal in fusion, when divided into small parts always takes a perfect globular form; when inclosed in a phial its surface is convex. This last phænomenon depends on mercury's having so little affinity with glass, and on the strong mutual attraction of the integrant parts of this metal; for when mercury is put into a metal vessel with which it has an affinity, its surface appears concave, like that of any other fluid, as it then combines with the sides of the vessel.

The taste of mercury is imperceptible to the nerves of the organs of taste; but it produces a pretty strong effect on the stomach and the intestines, as well as on the surface of the skin. Insects and worms are much more sensible of its taste than any other animal. Mercury kills them very quickly, and is therefore prescribed by physicians as an excellent cure

cure for worms. Some skilful physicians have been induced to think, from its possessing the power of curing the itch and several cutaneous disorders, that these are occasioned by certain insects penetrating thro' the texture of that organ. But this opinion has not been generally adopted, though several naturalists have described the animal which causes the itch, &c.

Mercury, when rubbed between the fingers, exhales a peculiar faint smell. If it be shaken when very pure, it is sometimes, and particularly in hot weather, observed to sparkle with a phosphoric light, which, tho' not strong, is yet sufficiently discernible. Many natural philosophers have observed this of the mercury of the barometer. On immersing the hand into this metallic fluid, a person feels a sensation of cold, which would suggest that its temperature is colder than that of the atmosphere: but on immersing a thermometer, we soon find the temperature of the mass of mercury to be the same with that of the atmosphere. This phenomenon, which eludes our observation, must be entirely owing to the mercury's attracting the heat from the hand with great rapidity; for mercury is known to be a powerful conductor of heat.

When mercury is divided by a rapid and continued motion, such as that of a mill-wheel, it is by degrees converted into a very fine black powder, called *Æthiops per se*, on account of its colour: as mercury is in this instance in some degree calcined, we call this powder *black oxide of mercury*. On being exposed to a moderate heat, or triturated in an hot mortar, it recovers its usual fluidity and metallic lustre.

Mercury is not one of those metals which are most plentiful in nature. It is found in the earth, either in a virgin state, possessing all its properties, or in a state of oxide, or in combination with acids, sulphur, and

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some other metallic matters : in this last state, it is said to be mineralized by these several substances.

Fluid mercury is found either in globules or in larger masses in earths and soft stones, and most frequently in the cavities and interstices of its ores. At Ydria in Spain, and in America, it is gathered in the cavities and clefts of rocks. Sometimes too it is found in clay at Almaden, and in beds of chalk in Sicily. Lastly, it is found among silver, and lead ores, as well as mixed with white oxide of arsenic.

M. Sage has discovered an ore of mercury in oxide from Ydria in Friuli. It is of a red brown colour, very soft and granulated in its fracture : globules of running mercury are sometimes found in it ; it is reducible by heat without addition. Mr Kirwan considers it as a combination of oxide of mercury with the carbonic acid. One hundred parts of this ore afford 91 of mercury.

In the year 1776, Mr Woulfe found, at Obermuschel in the Duchy of Deux-Ponts, an ore of mercury in crystals, ponderous, sparry, white, yellow, or greenish, which, on assaying it with alkalis, he found to contain both sulphuric and muriatic acid : it is a compound of sulphate of mercury with corrosive mercurial muriate. M. Sage affirms it to contain 86 parts of mercury to the hundred weight. The same chemist describes a brown corneous ore of mercury found in Canthia.

In nature, mercury is ofteneft combined with sulphur. The compound which it then forms is called *cinnabar*. This mineral substance is red, and has not the smallest degree a metallic appearance ; because though the proportion of the sulphur be very small, yet the two bodies are very completely combined together. *Cinnabar* is found in the Duchy of Deux-Ponts, in

the Palatinate, in Hungary, in Friuli, at Almaden in Spain, and in South America, where it chiefly abounds at Guamanga in Peru. It is sometimes in compact masses, varying in colour from a pale to a deep and blackish red; sometimes in transparent ruby-coloured crystals; and often in a sort of scales or foliated plates. When in a very bright red powder it is called *native vermilion*, or *cinnabar in flowers*. Lastly, it is found in various countries in sulphate of lime, and mixed with iron, pyrites, and silver.

Mr Cronstedt, in his mineralogy, speaks of an ore of mercury in which that substance is combined with sulphur and copper. That ore is of a blackish grey colour, brittle, and ponderous; its fracture is vitreous, and it decrepitates when exposed to fire. It is found at Muschel-Landsberg.

The same mineralogist affirms, that mercury has been often found amalgamated with virgin silver in the ore of Sahlberg in Sweden. M. Romé de Lille has in his cabinet a specimen which he thinks to be of this kind.

M. Monnet, in his system of mineralogy, speaks of an ore brought from Dauphiny in the year 1768, by M. de Montigny, which contains mercury, sulphur, arsenic, cobalt, iron, and silver. He has found it to contain in the hundred weight, a pound of mercury and three or four ounces of silver.

From this short account of mercury, as it exists in the interior parts of the earth, it appears that all its ores may be arranged under the following varieties.

State I. Native mercury.

In earths and stones, but oftenest in its own ores.

State I

State I

Varieties.

1.

2.

3.

4.

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State

State II. Native oxide of mercury.

State III. Native sulphate and muriate of mercury.

State IV. Mercury mineralized by sulphur; cinnabar.

Varieties.

1. Transparent cinnabar, of a red colour, and crystallized in very short triangular prisms, terminating in triangular pyramids.
2. Transparent red cinnabar in octohædral crystals, consisting of two triangular pyramids, joined at the bottom, and truncated.
3. Solid compact cinnabar, either of a brown red or a clear red colour. It is sometimes in leaves.
4. Red cinnabar, arranged in striæ, on a stony gangue, or on solid cinnabar. It is sometimes needled, like cobalt.
5. Cinnabar in flowers, native vermilion. This cinnabar is of a sparkling red colour resembling fatten, and adhering to various gangues in the form of a very fine powder; sometimes it is crystallized in very small needles, and it is then very like the last of the foregoing varieties.

State V. Mercury combined with sulphur and copper : Cronstedt's black vitreous ore of mercury.

State VI. Mercury mixed with sulphur, arsenic, cobalt, iron, and silver.

State VII. Mercury mixed with silver : native amalgam of silver.

In order to know the nature of an ore containing mercury, it must be pounded and mixed with lime, alkalis, &c, placed on a warm brick, and covered with a bell-glass ; the mercury is then reduced to vapours, and again condensed on the sides of the glass. If it be wished to know the quantity of the mercury which the ore contains, then after being pulverized and washed, it is distilled with some matters capable of combining with the sulphur, and so disengaging the mercury. Water is previously put into the receiver, and the mercury falls under the water. By weighing the ore exactly before assaying it, and afterwards the mercury obtained by distillation, it is known what quantity of the metal the ore can afford.

Virgin mercury is easily separated by grinding down the stones with which it is mixed, and diluting them in water. The metal is precipitated, and the earth mixed with the water. In this manner is the mercury extracted from the ores of Ydria in Friuli.

Cinnabar is never roasted ; because, as it is volatile, it would be dissipated by fire. But in nature, it is almost always mixed with a calcareous or a martial substance.

rance, which contributes as an intermedium to its decomposition with the help of fire.

Anthony de Jussieu has given, in the Memoirs of the Academy for the year 1719, a description of the process by which mercury is extracted from cinnabar at Almaden in Spain. That ore contains iron with a small portion of calcareous stone. It is put into furnaces of the form of a reverberating furnace; the furnaces are heated by combustible matters put into the ash-pan. The furnace has no apertures but eight holes with which it is perforated behind. To each of these holes a line of aludels is fitted; the last of which joins a small building at a pretty considerable distance from the furnace. Between the furnace and the structure where the rows terminate there is a small terrace on a level with the apertures of the furnace and the building. That terrace consists of two inclined planes, which support the aludels. If the aludels be any where so unskilfully joined as to suffer the mercury to escape, it is collected at the junction of the inclined planes of the terrace. When the fire is applied to the cinnabar, the iron and the calcareous stone absorb the sulphur; the mercury is reduced into vapour, enters the aludels, and passes towards the little building. After the distillation, all the aludels are conveyed into a square chamber, where they are emptied, and all the mercury collected into a pit in the middle of the chamber, towards which the floor is inclined, all around it.

Anthony de Jussieu observes, that cinnabar ore does not give out any exhalation noxious to vegetables, and that the grounds adjoining to the mines of Almaden are very fertile. He has also observed, that the working of those mines is not, as had been thought, injurious to the health of the workmen. Those who work in the

interior parts of the mine as slaves are the only sufferers; for the fire which they are obliged to kindle always volatilizes a portion of the mercury, and they are of consequence continually surrounded with mercurial vapours.

M. Sage, in the Memoirs of the Academy for the year 1776, has described the process by which mercury is extracted from cinnabar in the Palatinate. The furnace is a gallery containing forty-eight retorts of cast iron, each an inch in thickness and three feet nine inches in length, containing about sixty pounds of matter. These retorts are immoveably fixed upon the furnace. A mixture, consisting of three parts of ore well pounded, with one part of slaked lime, is introduced into them with brass ladles. It is heated with mineral coal put in at the two ends of the furnace, the sides of which are so perforated with holes as to admit enough of fresh air to make the coals burn. The heat, with the re-action of the lime on the sulphur, volatilizes the mercury, which is collected into earthen receivers fitted to retorts, and about a third part full of water. This operation takes up about ten or eleven hours.

Mercury obtained from cinnabar is very pure, and contains not a particle of extraneous matter; scarce any is to be got so pure in commerce. Almost all the mercury sold by merchants is more or less mixed with extraneous matters; it has the appearance of being a little tarnished, and instead of dividing into globules when it runs, it falls into a flat surface set round with points. The merchants then say that *it draws a tail*.

Mercury seems to suffer no alteration from light. It is one of those fluid matters which are the easiest and the most uniformly heated, that is, whose dilatation proceeds in the most constant manner. This has

been

been shown to be the case by Messrs Bucquet and Lavoisier, in their experiments on the effects of heat on different fluids; read before the Academy of Sciences. This phenomenon shows mercury to be the most proper fluid for forming accurate thermometers, by nicely indicating the degrees of heat.

This metallic fluid, when exposed to fire in close vessels, boils like other fluids. This property is not peculiar to it; silver, gold, and most other metals display the same phenomenon. It is true, that as mercury is more fusible than any other metal, it boils quicker, and continues to boil longer after being red-hot. Ebullition is nothing but the passing of a body from a liquid to a vaporous state. This vapour of mercury, which soon becomes very apparent in the form of a white smoke, and obscures the transparency of the vessels into which it is received, is condensed by cold into drops of liquid mercury; which, when the distillation has been carefully performed, are found to have suffered no loss nor alteration. Mercury is therefore a very volatile substance, which may be distilled like water, and in this property it bears a near relation to the semi-metals.

Boerhaave distilled the same quantity of mercury 500 times successively, without effecting any alteration upon it; only it appeared to become more sparkling, more ponderous, and more fluid; which might be owing to its being rendered more pure by distillation. He obtained a small quantity of grey powder, which appeared to be mercury very much attenuated, and became again fluid and brilliant on being triturated in a mortar. This was black oxide of mercury; and its production must have been owing to air contained in the distillatory apparatus.

Distillation is a method for purifying mercury, and

separating from it the fixed metals by which it is usually altered as it appears in commerce. The extraneous metal is found in the retort, forming in some places a brilliant, and in others a blackish crust. By weighing this residue, we learn what quantity of matter altered the mercury.

The extraordinary gravity of mercury has induced chemists to think that it contains a large proportion of the pure earthy principle or vitrifiable earth. But when that principle predominates in any body, it renders it solid; and instead of being solid, mercury is very fusible: the earthy principle is in an eminent degree fixed, but mercury very volatile. Beccher, observing this opposition between the qualities of mercury and those of vitrifiable earth, was induced to allow in this fluid the existence of a peculiar earth, to which he gave the name of *mercurial*, ascribing to it both gravity and volatility. Mercury was then, according to that chemist, a compound of three earths, vitrifiable, inflammable, and mercurial. But no person has as yet demonstrated the existence of the latter in any body, and the opinion is therefore to be considered as an assertion destitute of proof. Mercury appears to me to be like other metallic substances, a peculiar combustible body, the principles of which have not yet been separated. As to the vitrifiable earth, the properties of which we examined in the beginning of this work, we do not think that we can admit its existence in mercury any more than in the other metals, because no such principle is ever extracted from it. What Beccher and Stahl distinguished by that appellation in mercury and other metallic substances, is very far from being a simple earthy matter, as we showed when speaking of metallic oxides in general.

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Mercury in vapours has a considerable expansive force, and is capable of producing lively explosions when attempts are made to confine it. Hellot related to the Academy, that a certain person, wishing to fix mercury, put a quantity of it into an iron ball, well soldered together, and threw the ball into the middle of an hot furnace. But no sooner was it red hot than the mercury burst out and escaped with a considerable noise. M. Baumé relates, in his *Experimental Chemistry*, a fact nearly similar, to which Geoffroy the apothecary was witness.

Mercury is much more susceptible of calcination by the contact of air and of many other bodies, than it has till very lately been thought to be. A blackish grey pellicle is incessantly forming on its surface, which is a true mercurial oxide.

When heated with access of air, this metal changes in a few days into an earthy powder, which is red, brilliant, and disposed in small scales. This powder has nothing of a metallic aspect, and is really oxide of mercury. The alchemists thought that mercury was fixed in this operation, and therefore gave the powder the improper name of *precipitate per se*. As mercury, tho' very volatile, yet needs the concurrence of air in order that it may be calcined, a pretty convenient instrument, called *Boyle's bell*, has been contrived for the purpose. It is a very large broad crystal bottle; a quantity of mercury is inclosed in it; and as it forms a very thin layer, it of consequence exhibits an extensive surface. The stopper, which exactly fits the mouth of the bottle, is a crystal cylinder with a capillary pipe. The bottle is placed on a sand-bath, and heated till the mercury boil. The aperture of the cylinder is of such a size as to admit the air without suffering the mercury to escape.

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After digesting it in this manner for several months, the oxide formed on the surface of the mercury is separated. Its separation is effected by putting the whole upon a piece of thick cloth, and pressing it till the mercury pass through, leaving the oxide upon the cloth. A flat-bottomed matrafs is equally proper for the purpose. A quantity of mercury sufficient to form a thin stratum is poured into it: the neck of the matrafs is drawn out by means of a lamp into a capillar pipe, and the point broken off. This method, which we owe to M. Baumé, affords a vessel more proper for reducing mercury to an oxide, as it contains more air; it may also be heated with more ease and at less expence than *Boyle's bell*, and is not so easily broken. In order that this experiment may succeed, the mercury must be night and day for several months exposed to an heat sufficient to make it boil gently. By placing a number of matrasses on the same sand-bath, a greater quantity of precipitate *per se*, or red oxide of mercury, is obtained, and a certain quantity of it may even be prepared in fifteen or twenty days.

The precipitate *per se* is a true oxide of mercury, or a combination of this metallic substance with oxigene, which it gradually attracts from the atmosphere. What proves this in a convincing manner is, 1. That mercury can never be reduced into precipitate *per se* without air: 2. That vital air is necessary to the formation of this compound; none of the various gases can contribute to the oxidation of mercury: 3. That mercury in this instance gains an increase of weight: 4. That when the precipitate *per se* is heated in close vessels, it is entirely reduced to running mercury, giving out at the time a large quantity of elastic fluid, in which combustible bodies burn four times as quick as in com-

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mon air. The existence of this fluid was first observed by Dr Priestley; he gave it the denomination of *dephlogisticated air*; we call it *oxigenous gas* or vital air. Mercury, on being thus reduced, loses the increase of weight which it had acquired by being calcined.

M. Lavoisier, from considering the last of these facts, together with the other phænomena of calcination, indicating air to be necessary to and consumed during that operation, has inferred, by an analogy equally fair and probable with any other in physics, that metallic oxides are combinations of the metals with the oxigenous part of air. As the *precipitate per se* may be easily analysed by heat into two principles, pure vital air and running mercury, this instance contributes greatly to illustrate and establish the pneumatic theory. It may be easily understood in what manner the base of vital air, or oxigene fixed in mercury, disengages itself on regaining its elasticity by means of heat. Thus to reduce red oxide of mercury, it must be heated in very close vessels: if air be admitted, it remains still in the state of oxide, because it always finds in the atmosphere a body with which it is capable of uniting; the only body which possesses the power of calcining it. This is what induced M. Baumé to maintain that the *precipitate per se* was not reducible, but, on the contrary, was sublimed in reddish ruby-coloured crystals: while M. Cadet has asserted that all *precipitates per se* are equally reducible into running mercury. Macquer has proved, by an ingenious and natural account of the facts, that each of these chemists had good reason for what he advanced; and that when oxide of mercury is heated with concurrence of air, it is entirely sublimated, and may even be melted into a glass of a most beautiful red colour; as has been observed by Mr Keir a learned Scotch chemist,

chemist, in his translation of the Chemical Dictionary; whereas this same oxide, which is sublimated when exposed to the contact of air, is reduced to running mercury, and gives out vital air when urged with an intense heat in close vessels.

As the brilliancy is sullied by particles of dust deposited on its surface by the air, it has received the name of *the loadstone of dust*: But it appears that all bodies possess the same property; only the superior lustre of mercury renders it more observable in that metal. Besides, mercury suffers no alteration from the dust which it thus attracts; and on being filtrated through a piece of goat-skin to separate those extraneous particles, it recovers all its lustre.

Mercury appears not liable to solution in water: Physicians, however, are in use to hang a bag filled with mercury in ptisans to be given for worms,—while they are boiling. We are even assured, that experience has evinced the good effects of this practice: Lemery has proved, that mercury loses nothing of its weight in this decoction. Perhaps a principle analogous to smell may on that occasion exhale from this metal, so subtle and fugitive, that its weight cannot be distinguished, and may communicate an anthelmintic virtue to the water.

Mercury is not more disposed to unite with earths than the other metallic substances. Its red oxide, or *precipitate per se*, might be fixed in glasses, and colour them; as is observed of the oxide of arsenic.

We know not in what manner barytes, magnesia, lime, and the alkalis act upon mercury.

The sulphuric acid acts not upon this metallic substance unless when concentrated. To effect this solution, put into a glass retort one part of mercury, and
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pour upon it a part and an half of concentrated sulphuric acid. Let this mixture be heated; a lively effervescence is gradually raised; the surface of the mercury becomes white; and a powder of the same colour is separated, and being dispersed through the acid, renders it turbid. A considerable quantity of sulphureous gas is disengaged, and may be collected above mercury. This, as we have seen, when speaking of the sulphuric acid, is the process by which this gas is usually obtained. There passes at the same time a portion of water, containing sulphureous acid gas. When the distillation is continued till no more of the sulphureous acid can be produced, there is then found in the bottom of the retort a white, opaque, and very caustic mass, which weighs one third more than the mercury from which it is produced, and attracts a little moisture from the atmosphere. The greatest part of this mass is an oxide of mercury, which is combined with a small portion of sulphuric acid. This matter has been remarked by Kunckel, Macquer, and Bucquet, to be in its nature pretty much fixed. The sulphuric acid is decomposed by a double elective attraction: the mercury being a combustible substance combines with the oxygen of the acid, while the heat disengages the sulphureous gas and the water. The metal is then in the state of an oxide, and must of consequence be much more fixed than running mercury.

A part of this sulphuric mercurial mass is dissolved in water. The fluid, when liberally poured upon it, dilutes the mass, and, if cold, causes it to precipitate a white powder: if the water employed be boiling, the powder takes a beautiful bright yellow colour; and the hotter the water, and the greater the quantity of it poured on the mass, so much the more lively is the colour which the powder assumes. The most ancient
name

name of this matter was *turbith mineral*, or *yellow precipitate*: we call it yellow mercurial oxide. The water in which it has been washed is decanted off; boiling water is again poured upon it, and it now acquires a brighter yellow colour. A third washing purifies it from all remains of the sulphuric acid. It is now destitute of taste; and when urged with fire in a retort, it first becomes of a deeper colour, and is afterwards reduced to running mercury, giving out at the same time a considerable quantity of vital air. Kunckel mentions this reduction. It succeeded with Messrs Monnet, Bucquet, and Lavoisier, who traced it through all its circumstances. I have repeated it several times with success. It proves, as we have already seen, that the sulphuric acid consists of sulphur, oxigene, and water; but a pretty strong fire is requisite to reduce this oxide. Perhaps the reason why M. Baumé did not obtain running mercury, which has induced him to assert that this yellow oxide does not resume a metallic form unless some combustible substance be added, was his not having applied to it a sufficient heat. By continuing to heat the mercurial sulphuric mass in the same retort in which it was dissolved, without diluting or washing it to carry off the acid, we likewise decompose the oxide: it is reduced to running mercury when the oxigene which it had attracted from the sulphuric acid acquires elasticity, and becomes of consequence vital air by combining with heat.

The water poured on the white sulphuric mercurial mass receives that portion of the acid which is not decomposed, but remains in the mass. But as oxide of mercury is soluble in the sulphuric acid, that saline substance always carries off with it so much of the oxide; and the substance which remains dissolved in the water after the

reduction is therefore true sulphate of mercury. When evaporated by a strong heat, it deposits that salt in small needles; the form of which cannot be determined, because they are soft and very liable to deliquesce. If boiling water be cast on those crystals of sulphate of mercury, they become yellow and return to the state of mercurial oxide, the water separating the acid and leaving the oxide pure. The same thing happens when, after having evaporated the first lixivium of the mercurial mass by an intense heat, we, instead of crystallizing, dilute it in a large quantity of boiling water: it precipitates a yellow powder which is a true oxide. If cold water be used, the precipitate is white; but by pouring boiling water on the white precipitate we may render it yellow. We can likewise at pleasure render the solution of mercurial oxide decomposable or not decomposable in water. All that is requisite for this purpose is to evaporate the oxide by a violent heat, or to make the acid receive as much of the mercurial oxide as it is capable of dissolving: these two bodies are then easily separated by water. On adding a little of the acid, the fluid ceases to precipitate it. I received full conviction of this fact by dissolving *turbith mineral* well washed in the weak sulphuric acid. This solution not being overcharged with mercurial oxide is not precipitated by water. But if the acid be charged with as much as it can dissolve with the help of heat, which happens when the oxide is added till it refuse to dissolve it; such a solution, on being poured into cold water, forms a white precipitate, and a yellow precipitate when poured into hot water. If a little sulphuric acid be added to it when in this state, it ceases to yield a precipitate. The white mercurial oxide deposited by sulphate of mercury supersaturated with mercury, when poured into cold water

water is very soluble: we can make it disappear by adding sulphuric acid to the mixture.

Sulphate of mercury may be decomposed by magnesia and lime, which cause it to yield to a yellow precipitate. The fixed alkalis separate from it a yellow oxide nearly of the same colour: Ammoniac precipitates but very little of sulphate of mercury, and that very slowly. It is to be observed, that these precipitates of mercury vary in colour according to the state of the solution and the substance by which they are precipitated; the quantity varies too. A saturated solution gives the most copious precipitate. Again, if a solution not saturated with mercury be decomposed, each flake of the oxide separated by the first drops of the precipitant matters is again dissolved by the excess of acid. When this excess of acid is saturated, the precipitate is permanent. From this it appears, that the alkalis act rather on the acid in combination with mercury than on the free acid. All of these mercurial oxides precipitated by alkaline substances may be reduced by themselves in close vessels. In order to obtain them pure, we must wash them repeatedly with distilled water.

Mercury decomposes the nitric acid with the greatest rapidity. The solution is effected cold, and with more or less activity, according to the state of the acid. Common aquafortis acts upon mercury without giving out any great quantity of red vapour. When a little of the fuming nitrous acid is added, or the mixture heated, the re-action of the matters is then very rapid, a very large quantity of nitrous gas is disengaged, and the mercury reduced to oxide remains in solution. The liquor is greenish, but loses that colour at the end of a certain time. By this process, the nitric acid may be caused to receive a quantity of mercury equal to it-
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self in weight. Bergman has observed, in his Dissertation on the Analysis of Waters, that nitrous solutions of mercury differ from one another according to the manner in which they are prepared. That which has been effected cold, and without the disengagement of any great quantity of red vapour, is not decomposable by distilled water; but if the solution have been promoted by heat, and have given out a considerable quantity of nitrous gas, it will then be liable to precipitation by water, and cannot be employed in analyzing waters with any certainty of its effects; as we shall show when speaking of mineral waters. I take this phenomenon to be owing to the same cause in the nitrous solutions as in the solution by the sulphuric acid. The nitric acid may, with the help of heat, be supersaturated with oxide of mercury, which it holds suspended, if we may be allowed the expression. This solution, with an excess of mercury, may be precipitated by distilled water, which changes the density of the liquor, and diminishes the adherence of the mercurial oxide to the nitric acid. The precipitate is therefore a genuine oxide, which becomes very yellow if the supersaturated solution be poured into boiling water, but white when poured into cold water. It may be instantly coloured by washing it in hot water. Again, as the cold solution contains only nitrate of mercury without excess of oxide, heat being requisite to supersaturate the acid with the oxide, distilled water cannot therefore precipitate it. I am induced to think this by a fact which I have often observed; it is, that the same mercurial solution may be at pleasure rendered decomposable or not decomposable in water, by adding alternately mercury and acid, so as to make it pass from the one state to the other. All that is requisite for that, is to dis-

solve mercury cold in the nitric acid, suffering the acid to receive as much mercury as possible. This solution is not decomposable in water, though it gives out nitrous gas. On adding mercury till it be saturated with as much as it can dissolve with the help of heat, it is rendered susceptible of precipitation by water. The same theory very well explains why a nitrous solution, not liable to be precipitated by water, becomes so when heated. Heat disengages nitrous gas; and that can never be effected without destroying a portion of the acid: the proportion of the mercurial oxide to the acid then becomes greater: it is no longer combined with the mercurial nitrate; but only adheres to it, and is so suspended in it that it may be easily precipitated by water. I am certain that the precipitate which solutions of mercury yield by water is only an excess of oxide; and that the solution, after giving such a precipitate, still retains a portion of true nitrate of mercury, which may be decomposed by alkalis in the same manner as the sulphuric mercurial mass lixiviated in order to the preparation of *turbith* mineral. This portion of nitrate of mercury may even be crystallized. The excess of mercurial oxide which renders the nitric solutions susceptible of decomposition by water, is attended with another circumstance which promotes that decomposition. The oxide is so highly calcined or oxygenated as to have but little adhesion to the nitric acid.

The solution of mercury in the nitric acid is exceedingly caustic; it corrodes and destroys animal organs. When it falls on the skin, it produces deep purple spots, which at a little distance appear black. These continue till the epidermis fall off in scales. It is used

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in surgery as a powerful escharotic, under the name of *mercurial water*.

The solution of mercury in the nitric acid affords crystals, which differ in form, according to the state of the solution and the circumstances of the crystallization. On observing these varieties carefully, I distinguished four kinds of them very distinct from each other, which I shall describe.

1. A cold solution affords by spontaneous evaporation for several months very regular transparent crystals. M. Romé de Lille has described them very accurately. They are flat solid figures with fourteen sides, formed by the junction of two tetrahædral pyramids, cut very near the base, and truncated at the four angles which result from the junction of the pyramids.

2. If the same cold solution be evaporated by heat, and left to cool, it deposits at the end of four-and-twenty hours a kind of acute prisms, striated obliquely across their length, which are formed of small plates covering each other like tiles, in the manner which botanists call *imbricatim*. On a near examination of the elements of those irregular prisms, I perceived the plates to be solids with fourteen facets, resembling the crystals obtained by spontaneous evaporation, but smaller and more irregular.

3. A nitric solution effected by means of a moderate and well-managed heat gives, by cooling, crystals in very long and very acute flat needles, striated lengthwise. These are the crystals most commonly obtained from this solution; and they have been described by a great many chemists, by Macquer, Rouelle, Baumé, &c.

4. Lastly, If this solution be heated till it become de-

composible by water, it is then usually formed into an irregular white mass, resembling the sulphuric mass. I have sometimes seen, on that occasion, a confused mass of very long slender, flexile needles, glossy like tallow, and moved about with the motion of the liquor; they perfectly resembled the brilliant, silvered dendrites, which I have often observed on the sides of bottles containing *acetite of potash*, or *foliated earth of tartar*. It is proper to add, that this last solution of mercury gives irregular confused crystals, or shapeless masses, only because it contains an excess of the metallic oxide, and may therefore be rendered susceptible of regular crystallization by adding more of the acid.

These several nitrates of mercury exhibit nearly the same appearances. They are very caustic, and corrode the skin as well as their solutions; they detonize when put on burning coals. With respect to this property, it is to be observed, that it belongs in a much more eminent degree to the most regular crystals with fourteen faces, than to those which are in the form of small needles; and that the white mass precipitated from the solution, after it has been exposed to a strong heat, is entirely destitute of it. The detonation of nitrate of mercury is scarce observable in newly formed crystals; to render it more sensible, the nitrate must be left to dry for some time on blotting paper. If the crystals be then put on a burning coal, they melt, become black, and extinguish the flame of that part of the coal on which they lie. But their edges being dried, throw out little reddish sparks with a noise similar to a faint decrepitation. When dry, they emit a more lively whitish flame; but it very soon ceases.

Mercurial nitrate melts when heated in a crucible; very thick red vapours then exhale from it: as it loses
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its water and its nitrous gas, it assumes a deep yellow colour, which changes first to an orange, and afterwards to a bright red: in this state it has been called *red precipitate*. We distinguish it by the name of *red oxide of mercury by the nitric acid*. It should be made in matraffes with a moderate heat when it is meant to be employed in surgery as a caustic, in order that it may retain a portion of the acid to which it owes its corrosive powers: But when it is made very hot, it becomes merely oxide of mercury, formed by the combination of that metal with the oxigene of the nitric acid. Nitrate of mercury distilled in a retort, affords, in the first place, an acidulous phlegm and nitrous gas: it is now in the state of red precipitate. On being made very hot, it gives out a considerable quantity of vital air mixed with a little azotic gas; and the mercury is sublimated in a metallic form. This experiment made by M. Lavoisier with the utmost accuracy, led him to the discovery of the component principles of the nitric acid; as we have mentioned in our history of that acid.

Nitrate of mercury becomes yellowish, and is very slowly decomposed in the air. It dissolves readily enough in distilled water, is more soluble in boiling than in cold water, and crystallizes by cooling. When this salt is dissolved in water, part of it is precipitated without being dissolved, and acquires a yellowish colour. M. Monnet calls that matter *nitrous turbith*; and observes, that a good deal of it may be obtained by washing a nitric mercurial mass evaporated to dryness, as is done in preparing *red precipitate*. When nitrate of mercury is to be entirely dissolved, distilled water must be used, and aquafortis poured into it till the precipitate disappear. I have observed, that when

boiling water is poured on very pure nitrate of mercury, the salt becomes instantly yellow, and affords an oxide of a deeper colour, which on being exposed to fire, becomes red much sooner than that which owes its formation to the sulphuric acid. Yellow oxide of mercury by the nitric acid, is generally more completely calcined than that which is prepared with the sulphuric acid: the reason of which is, as we have already observed of other combustible substances, that the oxigene is more easily disengaged from the nitric than from the sulphuric acid. This is what renders the nitric acid more decomposable than the sulphuric acid.

Barytes, magnesia, lime, and the alkalis, decompose nitrate of mercury, and precipitate the mercury in the state of oxide. These precipitates vary in colour, gravity, and quantity, according to the state of the solution. The caustic fixed alkalis form a yellow precipitate, which is more or less brown or brick-coloured according to their causticity. Ammoniac causes the nitric solution of mercury in a good condition, that is, when water cannot decompose it, to yield a slate-grey precipitate; whereas the same salt produces a white sediment in a saturated solution of mercury liable to be precipitated by water: these distinctions have been very accurately observed by Bergman. These precipitates are merely oxides of mercury more or less calcined. They are all reducible without addition, by heat, in close vessels; and when reduced, they give out pure air. Those which have been precipitated by alkaline carbonates, afford a certain quantity of carbonic acid by the action of heat. Those which have not been precipitated by carbonates, but only exposed to the contact of atmospheric air, display the same phenomenon, for they absorb that acid from the atmosphere; a property

perty which is common to all oxides of mercury, and even to those of several other metals.

Oxides of mercury precipitated from solutions by alkaline intermedia, possess a peculiarity which has been discovered by M. Bayen, and is worthy of being here taken notice of. They detonize like gun-powder when exposed in an iron spoon to a gradual heat, after being triturated with flowers of sulphur in the proportion of half a drachm to six grains. After the detonation, there remains a violet-coloured powder, which may be sublimated into cinnabar.

The sulphuric acid, and the salts into which it enters, are also capable of decomposing nitrate of mercury; for this acid has a greater affinity than the nitric acid with mercury. If a portion of sulphuric acid, or of a solution of sulphate of potash, sulphate of soda, &c. and in general of any sulphuric salt, be poured into a nitric solution of mercury, a whitish precipitate is formed, if the solution be not saturated; which inclines more to yellow in proportion as the mercurial nitrate contains less acid, and more mercurial oxide. This precipitate is either sulphate of mercury or yellow oxide. M. Bayen has observed that it always retains a little nitric acid.

The muriatic acid does not act in a sensible degree on mercury; although it has a greater affinity with the oxide of this metal than any of the other acids. It combines with the oxide to form a peculiar salt. This combination takes place whenever the muriatic acid is brought into contact with that oxide, and the oxide divided into very minute particles. If a little muriatic acid be poured on a nitric solution of mercury, the acid seizes the oxide of the metal, and forms with it a salt which is precipitated in a kind of whitish coagulum,

called *white precipitate*. Muriatic salts with alkaline or salino-terreous bases, produce precisely the same effects, and form besides nitric salts, differing according to their bases. But it is of importance to observe concerning this precipitation, that it does not take place if the oxygenated muriatic acid be employed; for though that acid attracts the oxide of mercury from the nitric acid, the salt which it forms with it is very soluble in water; whereas that which the common muriatic acid forms with this acid is not at all soluble in water.

This acid has likewise a greater affinity with oxide of mercury than the sulphuric acid has; and when poured into solutions of this metal with the sulphuric acid, it produces precipitates in the same manner as in solutions of mercury with the nitric acid. The compound of the muriatic acid with oxide of mercury is capable, as above observed, of two different states, according as the acid is simple or oxygenated: with the oxygenated muriatic acid it constitutes corrosive mercurial muriate; with the simple muriatic acid, it is mild mercurial muriate.

There are several ways of preparing *corrosive sublimate*, or corrosive mercurial muriate. The most common way is, by mixing equal parts of dried mercurial nitrate, decrepitated muriate of soda, and calcined or white sulphate of iron or *martial vitriol*; putting this mixture into a matrafs, of which two thirds must remain empty; immersing the mixture into a sand-bath, and heating it gradually till its bottom be made red hot. The sulphuric disengages the muriatic acid from the soda: the soda again separates the nitrous acid from the mercury, which has robbed it of part of its oxygen; and becomes of consequence oxygenated muriatic

riatic acid: After that, it combines with the oxide of mercury, and forms corrosive mercurial muriate, which is sublimed into flat pointed crystals, that fix on the upper part of the matrafs. The nitric acid is dispersed in nitrous gas; the residue is reddish or brown, and contains oxide of iron and sulphate of soda, formed by the combination of the sulphuric acid with the base of the marine salt. In Holland, this salt is prepared in the great way, by triturating together equal parts of mercury, muriate of soda, and sulphate of iron, and exposing the mixture to an intense heat. In this way of preparing *corrosive sublimate*, the sulphuric acid, disengaged by heat from sulphate of iron, appears to convert the simple into oxygenated muriatic acid; for no other but this last acid could dissolve all the mercury employed on the occasion. Corrosive mercurial muriate may be likewise obtained, by sublimating a mixture of sulphate of iron, muriate of soda, and mercurial precipitate by fixed alkali, or any other kind of mercurial oxide.

Boulduc has given a very good process for preparing corrosive mercurial muriate: but Spielman remarks, that it was before suggested by Kunckel in his Chemical Laboratory. It consists in heating in a matrafs equal quantities of sulphate of mercury and decrepitated muriate of soda. Muriate of mercury is volatilized, and what remains is only sulphate of soda. This mode of operation affords very pure corrosive mercurial muriate, whereas that which we get in commerce, and even that which is prepared in the small way with sulphate of iron, always contains some mixture of iron. Boulduc's process is both easier and less expensive. It likewise proves, that the sulphuric acid possesses the property of oxygenating the muriatic acid.

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M. Monnet informs us, that he obtained this salt also by treating in a retort very dry muriate of soda with mercurial oxide, precipitated from the nitrous solution of mercury by fixed alkali. In all these processes for preparing corrosive mercurial muriate, the operator should beware of breaking the vessel containing the sublimate till it be perfectly cool, lest he suffer from the vapours of the salt. Lastly, There is yet another and more expeditious way of preparing corrosive mercurial muriate: it consists in pouring oxygenated muriatic acid into a solution of nitrated mercury, and evaporating the mixture slowly: when the nitrous acid is disengaged, the liquor affords, by cooling, crystals of corrosive mercurial muriate. There is reason to think, that when Scheele's oxygenated muriatic acid becomes better known, apothecaries will prepare corrosive mercurial muriate either by this last process or by simple solution.

Corrosive mercurial muriate is a neutral saline substance, which well merits the attention of chemists and physicians. It possesses a number of valuable properties, of which we shall give the history. This salt has a very caustic taste. When but the smallest quantity touches the tongue, it leaves for a long time after a stiptic and metallic impression, which is very disagreeable. This impression extends even to the larynx, shutting it spasmodically; and it remains long, particularly on persons of very delicate nerves. This salt acts in a still more sensible manner on the coats of the stomach and the viscera. When suffered to act upon them for some time, it corrodes them, so as to destroy their substance: It is of consequence one of the strongest poisons known. The causticity of corrosive mercurial muriate appears to depend on the state in which the

the mercury exists in the salt, as has been very ingeniously explained by Macquer. It cannot, as some authors have imagined, be ascribed to the muriatic acid; for the quantity of the mercury is more than three times as much as that of the acid. Accordingly it has been observed by Rouelle, that this salt communicates rather a green than a red colour to syrup of violets. The taste, too, of corrosive mercurial muriate is much stronger than that of the muriatic acid. A person may take a drachm of muriatic acid diluted in water, without suffering any harm: whereas a few grains of corrosive mercurial muriate taken in the same quantity of water are a certain poison. Bucquet thought this excessive sapidity to depend on the combination of the two bodies which compose this salt. One of his strongest proofs was drawn from that law of the affinity of composition by which it is established, that compounds possess new properties entirely different from those of the bodies of which they are compounded.

Corrosive mercurial muriate suffers no sensible alteration from light. Heat volatilizes and half vitrifies it. When exposed to a strong heat in the open air, it is dissipated in a white smoke; the effects of which are very energetic, and very noxious to the animal œconomy. When heated slowly and by degrees, it is sublimated in a regular crystalline form. Its crystals are prisms, so compressed that it is impossible to determine the number of their faces. They terminate in very acute points; and have been with good reason compared to the blades of poignards thrown very confusedly together. Fire does not decompose this salt; it suffers no alteration from air. It dissolves in nineteen parts of water, and crystallizes by evaporation into flat prisms,

very acute at their extremities, resembling those obtained by sublimation. The spontaneous evaporation of its solution afforded both me and M. Bucquet several times oblique-angled parallelipeds, with their extremities truncated slopewise. M. Thouvenel has obtained that salt crystallized in hexahædral prisms, a little compressed.

Barytes, magnesia, and lime decompose corrosive mercurial muriate, causing it to yield a precipitate of oxide of mercury. The *phagedenic water* used by surgeons as a corrosive, is prepared by casting half a dram of this salt in powder into a pound of lime-water; a yellow precipitate is formed, which renders the liquor turbid, and it is employed before the precipitate subsides. The fixed alkalis separate from corrosive mercurial muriate an orange oxide, which when suffered to settle for some time, acquires a deeper colour. Ammoniac causes this salt to yield a white precipitate; which, however, soon assumes a slate colour.

The acids, and the alkaline neutral salts, produce no alteration on corrosive mercurial muriate.

This salt contracts an intimate union with ammoniacal muriate; but neither of them is decomposed. Either by sublimation, or by crystallization, it forms with it a very singular saline compound, which the alchemists valued highly, and called *alembroth salt*, *salt of art*, *salt of wisdom*, &c. The ammoniacal muriate renders the corrosive mercurial muriate very soluble; for according to M. Baumé, three ounces of water containing nine drachms of the former salt dissolve five ounces of the latter. This last solution is effected with the help of heat, and when it cools, the salt subsides into a mass. With this salt a preparation is made up which is called *white precipitate*. It is prepared by casting into a solution of a pound of ammoniacal muriate

ate an equal quantity of corrosive mercurial muriate in powder. When this salt is fully dissolved, a solution of carbonate of potash is poured into the mixture and produces a white precipitate: this precipitate is washed, formed into little balls, and dried in the air. In this operation the potash disengages the ammoniac; which, in its turn, precipitates the mercury in a white oxide. This precipitate becomes yellow when exposed to heat, or even to light.

Corrosive mercurial muriate is altered by hydrogenous gas. Sulphur produces no change on it, but alkaline sulphure decomposes it as well as the other solutions of mercury: the immediate product of this decomposition is a black precipitate which results from the combination of the sulphur with the mercury. Most of the semi-metals which we have examined are capable of decomposing this salt: and as each of these instances of decomposition is attended with peculiar phenomena, they therefore deserve to be separately and carefully examined.

When two parts of corrosive mercurial muriate with one of arsenic are distilled by a moderate heat, there passes into the receiver a matter of the consistency of oil, and transparent, of which one part is very soon condensed into a kind of white jelly, improperly called *corrosive oil*, or *butter of arsenic*. If the heat be continued after this product has passed off, running mercury is obtained; and by this process we may attain an accurate knowledge of the principles of corrosive mercurial muriate. Muriate of arsenic does not appear to be susceptible of crystallization; it melts by a moderate heat, and its taste is so caustic that it instantaneously destroys our organs. It dissolves in water, by which it is partly decomposed: we are ignorant of its other properties. It cannot

be obtained with oxide of arsenic ; because when that semi-metal is already saturated with oxigene, it cannot disengage mercury from its combination with the muriatic acid by absorbing oxigene.

The effects of nickel, cobalt, and manganese, on corrosive mercurial muriate, have not yet been examined. As to bismuth, antimony, and zinc, those three semi-metals decompose this salt very readily. By distilling two parts of corrosive mercurial muriate with one of bismuth, we obtain a thick fluid substance, which congeals into a kind of greasy mass that melts on being exposed to heat, and yields a precipitate when plentifully washed : in a word, this compound is solid muriate of bismuth. Poli, who has given an account of this process in the History of the Academy for the year 1713, tells us, that when this *butter of bismuth* is several times sublimated, there remains in the vessel a powder coloured like oriental pearls, very soft and gluey : He proposes the use of this powder in painting.

When twelve ounces of antimony are completely mixed with two pounds of corrosive mercurial sublimate, the mixture gives out heat : a circumstance which proves that these two bodies act rapidly on each other. On distilling this mixture by a moderate heat, we obtain a thick liquor which is fixed in the receiver, and often even in the neck of the retort, into a white mass called *butter of antimony*. The quantity of this sublimated muriate of antimony is commonly sixteen ounces and a few drachms. The residue consists of mercury and a grey powder of antimony which swims on the surface of the metallic fluid. On continuing the distillation after the muriate of antimony has passed into the receiver, and using a new balloon, we obtain running mercury ; but it is contaminated with a little muriate

of

of antimony, as that substance cannot be entirely taken away from the neck of the retort. M. Baumé, who has given a good account of this operation, says, that by this process twenty-two ounces of running mercury may be obtained, one ounce of antimony in powder mixed with mercury, and six drachms twenty four grains of antimony melted in the retort. The antimony is partly calcined: it affords a red and partly white oxide, which is sublimed. In this instance the antimony is calcined by the oxigene separated from the mercurial oxide, and combines with the muriatic acid to form muriate of antimony. This decomposition likewise takes place when sulphure of antimony is employed. By distilling one part of that mineral in powder with two parts of corrosive mercurial sublimate, sublimated muriate of antimony is obtained; but the residue, instead of containing running mercury, is a combination of mercury with sulphur. That combination may be sublimated by a very strong heat into red needles, which are improperly called *cinnabar of antimony*.

Sublimated muriate of antimony, or the combination of the muriatic acid with antimony, is not produced unless when the semi-metal attracts from the mercury the oxigene which it contains; as has been already observed of arsenic. This compound is in a crystalline form. It crystallizes into very large parallelopipeds. It is so caustic, that it instantly destroys our organs and burns vegetable matters. It is very liable to alteration by the contact of light. It melts with the most moderate heat, and becomes fixed by cooling: it is this property which has procured it the name of *butter of antimony*. It readily loses its whiteness, and takes a colour. It may be rectified by distillation. It attracts the moisture of the
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atmosphere, by which it is again dissolved into a thick and seemingly oleaginous fluid: in water it is dissolved only in part; for the greatest portion of it is decomposed by that fluid. When sublimated muriate of antimony is cast into distilled water, it immediately gives a very copious precipitate, which is called *emetic powder*, or *powder of Algaroth*, from the name of an Italian physician who used it as a medicine. It has likewise been improperly called *mercury of life*. This precipitate is an oxide of antimony strongly purgative and emetic, even when given in very small doses of three grains and an half to the doze. In order to render it very pure, it must be repeatedly washed in distilled water. It differs in possessing these properties from the other oxides of this semi-metal, which are far from acting in so energetic a manner on the animal œconomy. A portion of this oxide is dissolved in the water, in which muriate of antimony is washed, by means of the acid which mixes with the fluid. We have an opportunity of observing this fact on pouring a little alkali into that liquor: a white precipitate is produced in considerable abundance; and butter of antimony therefore appears to owe its property of being decomposable in water to its containing an excess of this oxide; and its forming into a solid mass may be attributed to the same cause. Sublimated muriate of antimony dissolves with heat and effervescence in the nitric acid. From that solution there is disengaged a large quantity of nitrous gas, which excites a considerable emotion in the mixture; the muriate of antimony disappears, and the liquor appears of a reddish yellow colour. This is a solution of oxide of antimony in the nitro-muriatic acid. It very soon deposits the oxide of antimony in the form of a powder, and even of a white magma. If the solution

tion of muriate of antimony by the nitric acid be evaporated to dryness as soon as made, it yields a very white oxide: It is diluted with a quantity of the same acid equal to its own weight, and again evaporated: the powder is yet a third time mixed with the same quantity of nitric acid and evaporated to dryness: it is then heated in a crucible, which is kept red hot for about half an hour, and after that suffered to cool. The oxide now taken out of the crucible is white above, and rose-coloured on the under part. The two portions are mixed, and form by their mixture what is called *Bezoar mineral*. Macquer considers this medicine as a perfect oxide of antimony, and thinks it to be the same with *diaphoretic antimony*. Lemery, however, who has given an accurate description of this preparation, advises to calcine it till it have scarce any acidity; wishing it to retain *some* acid, which must certainly change the properties of the oxide of antimony.

Corrosive mercurial muriate is decomposed by zinc, as has been asserted by Pott, and as I myself have found by repeated experiments. If you distill in a glass retort a mixture consisting of two parts of this salt with one of zinc in filings, or coarse powder, a white and solid salt ascends from the mixture, and is crystallized in small needles joined together in a form resembling the little bundles of which stalactites consist. This muriate of zinc emits a thin smoke when it is taken out of the receiver: it melts by a moderate heat; is coloured by inflammable vapours; and lastly, is partly decomposed in water like sublimated muriate of antimony.

The most singular property which corrosive mercurial muriate exhibits in regard to the alterations which it suffers from metallic substances, as well as the most important property which it possesses, is its power

of combining with running mercury. When saturated with that metallic fluid it loses most of its properties, particularly its taste and solubility. The old way of producing this combination was by trituration in a glass mortar corrosive mercurial muriate with running mercury, adding the mercury by degrees till it refused to unite with the mercurial muriate. Lemery and M. Baumé have observed, that the salt takes up a quantity of mercury equal to about three fourths of its own weight. The mixture was then put into small phials, two thirds of each of them being left empty, and sublimated three times successively. Care was taken to separate at each time a white powder, which is found above the sublimated matter, and is very corrosive. This product is called *sweet sublimate*, *mercurius dulcis*, or *aquila alba*: It ought to be called *sweet mercurial muriate*. Its insipidity, its crystalline form, and its being almost absolutely insoluble, distinguish it from corrosive mercurial sublimate. The crystals which it affords by slow sublimation are tetrahædral prisms terminating in four-sided prisms. We often find among them two very long tetrahædral pyramids, joined at the base, and forming very acute octohædrons.

The process for preparing sweet mercury, which we have here described, is attended with several inconveniences. To triturate corrosive mercurial muriate with running mercury till the mercury be entirely confounded with the mercurial muriate, is a very tedious and a very difficult task. A very minute acrid dust arises from the mixture while it is triturated; and the operator must bind a cloth over his mouth and nose to secure himself against the dangerous effects of that dust. The mercury is never entirely incorporated with the mercurial muriate; and the sublimation is very slow. M.

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Baumé advises to pour a little water on the matters as they are triturated. That fluid assists the trituration, and hinders the saline dust from rising. He likewise employs levigation, which contributes greatly to make the mercury incorporate with the salt. Lastly, to make sure of obtaining mild mercurial muriate without the least mixture of corrosive, Zwelfer, Cartheuser, and M. Baumé propose to pour on mild mercurial muriate, after it has been once sublimated, a quantity of hot water to dissolve the corrosive muriate, and then dry the salt, which is after this found to be much milder than before. M. Cornette, to hinder the volatilization of the corrosive mercurial muriate triturated with the mercury, proposes to make use of nitrate of mercury precipitated by ammoniac, which unites with corrosive mercurial muriate much more readily than running mercury. But as this oxide is not so pure as mercury, we cannot depend so much on the virtues of the preparation into which it enters. M. Bailleau, an apothecary in Paris, has given the Royal Society of Medicine a process for preparing mild mercurial muriate, without being exposed to any of those accidents which render the preparation of it in the common way so very dangerous. This process consists in forming a paste with corrosive mercurial sublimate and water, and triturating it with running mercury. Half an hour's trituration is here sufficient; because the water contributes to confound the two substances together. The process ends with digesting the mixture on a sand-bath by a moderate heat; the matter changes its original grey colour for white, and forms a very mild mercurial muriate, which needs only to be sublimated, in order that it may be perfectly pure.

M. Baumé has made several experiments on mild

mercurial muriate. He has shown, that it cannot receive an additional quantity of mercury; that it cannot exist in a middle state between corrosive and mild mercurial muriate; as where a smaller portion of mercury is mixed with the corrosive mercurial muriate than what is requisite to make it pass into the state of mild mercurial muriate, a portion of this latter salt is formed, in proportion to the quantity of the mercury and the excess of the corrosive; and the rest of the corrosive mercurial muriate is volatilized without suffering any alteration of its properties. These two compounds are separable by hot water.

From the researches of the same chemist we learn farther, that it is possible to change the mild into corrosive mercurial muriate, by sublimating it with decrepitated marine salt and white calcined sulphate of iron. In this operation the muriatic acid being disengaged and oxygenated by the sulphuric acid, unites with the mercurial oxide of the mild mercury, and converts it into corrosive muriate. M. Baumé is convinced that mild mercurial muriate differs greatly from the corrosive, as it cannot unite with ammoniacal muriate as the corrosive mercurial muriate does in the preparation of *alembroth* salt, or ammoniaco-mercurial muriate. It is even from the consideration of its possessing this property, that he advises to wash mild mercurial muriate with water impregnated with a little ammoniacal muriate, to carry off all the corrosive mercurial muriate which renders that salt so very soluble. Lastly, he has discovered, that at each sublimation mild mercurial muriate loses a part of its mercury, and affords of consequence a certain quantity of corrosive mercurial muriate; so that by repeated sublimation mild mercurial muriate may be entirely changed into corrosive. From this last fact it follows, that the medicine, known by the name of *mercurial panacea*, which

which consists of mild mercurial muriate nine times sublimated, is so far from being rendered milder by being so often sublimated, as most chemists and physicians think, that at the end of the process it differs in no respect from what it was at first. A circumstance attending the operation may be considered as a farther proof of this assertion; at each sublimation a small quantity of white powder which rises first is taken off, which powder is nothing but corrosive mercurial muriate. It is to be observed, that there remains in the phials a reddish powder when mild mercurial muriate is prepared. It is an oxide of iron produced from the sulphate of iron, which is employed in preparing the common corrosive mercurial muriate. Part of that oxide ascends with the salt in its sublimation; nay, the mercurial salt in vapour is often found to carry up with it even pieces of glass.

Late experiments on the oxygenated muriatic acid render the theory of the formation of mild mercurial muriate much more clear and intelligible than it formerly was. It has of late been proved, that corrosive mercurial muriate is a compound of oxygenated muriatic acid with oxide of mercury, and that mild mercurial muriate is formed by the common muriatic acid with the same metallic oxide: or, what amounts to the same thing, that in corrosive muriate the oxide is much more calcined than in mild muriate. Thus when running mercury is triturated with corrosive mercurial muriate, the mercury seizes the excess of oxigene contained in the muriatic acid, or in the former mercurial oxide; and as a larger quantity of mercurial oxide, and that less completely calcined, now combines with the same quantity of muriatic acid, the nature of the salt is of consequence altered, and it becomes less saline, more insipid, and more insoluble: in a word, its qualities

are weakened in proportion as the quantity of the mercurial oxide is increased.

The boracic acid does not dissolve mercury without an intermedium ; but, in the state of oxide, it acts in a very discernible manner on this semi-metal. These two substances may be combined by the way of double affinity. When a solution of common borax is poured on a nitric solution of mercury, a very copious yellow precipitate is produced, which was first made known by M. Monnet. In this operation the soda of the borax, uniting with the nitric acid, forms nitrate of soda ; while the boracic acid unites with the mercurial oxide to form an almost insoluble neutral salt which is precipitated. The liquor being filtrated and evaporated, affords fine brilliant pellicles of mercurial borate. We must, however, observe, that the salt contains a portion of oxide of mercury not combined with the boracic acid, because there is always an excess of soda in common borax. To obtain borate of mercury by this process, the borate of soda employed must be fully neutralized, that is, completely saturated with boracic acid. This salt, when exposed to the air, turns sensibly green ; ammoniacal muriate renders it very soluble, and forms with it a compound resembling ammoniaco-mercurial muriate. Lime-water makes it yield a yellow precipitate ; the colour of which changes to a deep red : with potash it yields a white precipitate. According to the academicians of Dijon, corrosive mercurial muriate is likewise decomposed by borax, which produces in a solution of it a brick-coloured precipitate. Water boiled over this precipitate becomes of a lacteous appearance on the addition of a fixed alkali ; which proves it to contain mercurial borate.

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We know not, in what manner the fluoric acid acts upon mercury; and we are no less ignorant of the effects which the carbonic acid produces upon it. We know only that water impregnated with this acid never acts upon mercury; though solutions of mercury decomposed by alkaline carbonate afford precipitates very different from those produced by the same salts in a pure caustic state, and mercurial oxide readily absorbs carbonic acid from the atmosphere.

The neutral salts have but very little power of action on mercury. Although this assertion chiefly regards the various sulphuric salts, yet I have remarked, that quicksilver incorporates readily with sulphate of potash.

Mercury does not appear capable of altering ammoniacal muriate by distillation. Bucquet, who made this experiment, has observed, that one part of the salt is not quite sufficient to absorb two parts of mercury, and the mixture gives no ammoniac by distillation. Yet the Count de Garaye had made up with these two substances a medicine to which he gave the name of *tincture of mercury*. Macquer, on examining his process, found it to be perfectly consistent with what he had advanced. It consists in triturating in a marble mortar an ounce of running mercury with four ounces of ammoniacal muriate, moistening the mixture with a little water till the mercury be entirely incorporated with the salt, leaving that matter then exposed to the air for five or six weeks, and shaking it from time to time. It must, at the end of this time, be triturated anew, put in a matrafs upon a sand-bath with good alcohol swimming above the powder to the depth of two inches, and caused to boil gently. The alcohol acquires a yellow colour, and appears to contain mercury from

its communicating a white colour to a plate of copper. It appears, that in this operation the ammoniac is gradually disengaged by the mercury, forming of consequence ammoniaco-mercurial muriate, of which part is dissolved by the alkali; and that the difference in the quantity of the mercury, and the gentle action which takes place during the maceration, are the causes why this experiment gives a result different from Bucquet's.

We know not in what manner hydrogenous gas acts upon mercury. Mercury combines very well with sulphur. When one part of this metallic fluid is triturated with three parts of sulphur, the mercury is by degrees confounded with the sulphur; and the result is a black powder, black sulphure of mercury, or *Æthiops mineral*, the colour of which deepens when it is suffered to lie aside. This combination is produced more quickly when the mercury is mixed with melted sulphur: on shaking that mixture it becomes black, and easily takes fire. In order to make it retain its black colour, it must be taken out of the fire, the flame must be quenched as soon as it appears, and the matter stirred till it become solid, and form into lumps. It is then reduced to powder, and passed through a fine sieve. Black sulphure of mercury is not the most intimate possible combination of sulphur with mercury. When this compound is exposed to an intense heat, it kindles, most of the sulphur burns, and there remains, after that combustion, a matter which, when pulverized, takes a violet colour. This powder is put into a matrass, which is heated till its bottom become red: it is kept for several hours in that state till the matter be sublimated. In the upper part of the matrass there is found after the sublimation a quantity of artificial cin-

nabar,

cinnabar, or red sulphure of mercury cryſtallized in needles of a brown red colour. Its colour is more lively, and not ſo deep when it is ſublimated in retorts. The Dutch prepare cinnabar for the arts in the great way. This compound is ſcarce volatile; and of conſequence a very intense heat is requiſite to ſublimate it. When much divided by levigation, it takes a bright red colour; and is then called *vermillion*. If heated in open veſſels, the ſulphur, which amounts to one-fourth of the whole quantity, burns by degrees, while the mercury is volatilized. Many ſubſtances have ſuch an affinity with ſulphur as to decompoſe red ſulphure of mercury. Lime and alkalis poſſeſs this property. When they are heated in a retort with this ſulphure, in the proportion of two parts of the ſulphure to one of the lime or alkali, running mercury is obtained, and the reſidue is alkaline or earthy ſulphure. M. Baumé has even obſerved this decomposition to take place in the humid way, when red ſulphure of mercury is boiled with liquor of fixed alkali. It is remarkable, that the alkali which he employed was not efferveſcent. Several of the ſemi-metals, ſuch as cobalt, biſmuth, and antimony, likewise poſſeſs the property of attracting ſulphur from mercury. We will ſee, that almoſt all the metals, lead, tin, iron, copper, and ſilver, have a greater affinity than mercury with ſulphur; and of conſequence decompoſe *cinnabar*: they may be therefore uſed indifferently to ſeparate the mercury of that compound. This metallic fluid, when obtained by ſuch a proceſs, is perfectly pure. It is diſtinguiſhed by the name of *mercury revived from cinnabar*.

Mercury inſtantly decompoſes alkaline ſulphures; but the decomposition is attended with different phænomena, according to the differences of the nature

nature of those compounds. With the alkaline sulphures it forms black sulphure of mercury, which at the end of several years is found to have changed its black colour for red. With ammoniacal sulphure, it is very readily converted into black sulphure of mercury, which in a few hours, or at most in a few days, takes a bright red colour. The yellow and the red oxide of mercury formed by fire or acids, exhibit sooner or later the same phenomenon with ammoniacal sulphure. It is produced also by pouring that liquor into solutions of mercury, and exposing the black precipitate which results from the mixture to a new quantity of ammoniacal sulphure.

I have discovered that running mercury shaken in water impregnated with hydrogenous gas, sulphurated either naturally or artificially, decomposes it very readily, and changes it into a black sulphure.

We know not in what manner mercury acts upon arsenic. Cobalt does not combine with this metal. Bismuth is easily dissolved by mercury, and combines with it in any proportion. From this combination there results a bright friable matter, which is more or less solid, according to the quantity of the bismuth. This amalgam crystallizes into four-sided prisms, which sometimes unite into octohædrons; but it is most frequently crystallized into thin plates of no regular form. This crystallization is effected by melting the combination, and suffering it to cool slowly. When heated in a retort, it gives out, but very refractorily, the mercury which serves as its solvent.

Mercury does not unite with either nickel or antimony. It combines with zinc by fusion. The amalgam which it forms with that semi-metal is solid: it is rendered fluid by trituration. When it is melted and

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suffered to cool slowly, it crystallizes into plates, which appear to be square and rounded on the edges.

Mercury is much used in the arts, such as gilding, silvering of glass, the construction of meteorological instruments, metallurgy, &c. This semi-metal is used in medicine almost under every form.

1. Crude mercury was formerly used in the volvulus or iliac passion. It is still boiled in water, and is thought to communicate the properties of a vermifuge. It is mixed with fats, and applied as an ointment in venereal complaints.

2. *Turbith mineral*, or yellow oxide of mercury by the sulphuric acid, has been recommended in the same cases, in doses of a few grains. This medicine is emetic and purgative, and often acts too powerfully in both ways.

3. Mercurial water, or its nitric solution, is used by surgeons as a powerful escharotic. Red precipitate, or red oxide by the nitric acid, serves the same purpose. There is a citron-coloured ointment made up of hog's-lard and the nitrous solution of mercury, which is an excellent cure for the itch.

4. Corrosive mercurial muriate has been recommended by Sanches and Van Swieten in venereal cases. A few grains of it are dissolved in *aquavita*, and the solution is taken by spoonfuls, diluted in a large quantity of some cooling drink. The state of the breast should be attended to when this medicine is administered, and it ought to be given with great caution. Mild mercurial muriate is given in doses of twelve or fifteen grains as a purgative, and in doses of three or four grains as an alterative. Phagedenic water is used in surgery, to corrode and destroy proud flesh, &c.

5. Mercurial borate has been successfully employed
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in venereal cases by M. Chauffier, the younger, of the Academy of Dijon.

6. *Cinnabar* has been undeservedly considered as antispasmodic and sedative. It is one of the principles of Stahl's *pulvis temperans*, which, according to the pharmacopœia, is prepared by mixing exactly three drams of sulphate of potash and nitre with two scruples of artificial *cinnabar*. This medicine is administered by exposing the sick person to its vapour; and this is one way of treating people ill with the venereal disease by fumigation.

All the preparations of mercury which are given internally, suit many other cases besides venereal complaints: Such are almost all cutaneous disorders, a scrophulous habit, swellings of the lymphatics, &c. Yet we cannot avoid observing, that these medicines, and especially all saline preparations of it, ought to be employed by none but skilful and cautious physicians; it is dangerous for the health, and even for the lives of mankind, that mercurial medicines should be in the hands of such a number of people who are destitute of the knowledge requisite to administer them; not only so as to be beneficial, but even so as not to do harm. I have oftener than once been witness of the unhappy effects produced by those preparations, in consequence of their having been administered by ignorant persons, with that rashness which usually accompanies ignorance. We even think this an object of sufficient importance to merit the attention of government.

CHAP.

C H A P. XVI.

Of Tin.

TIN, the *Jupiter* of the alchemists, is an imperfect metal of a white colour, brighter than lead, but darker than silver. It is very pliant, and when bent produces a crackling noise, called *the cry of tin*. We have already taken notice of the same phænomenon as belonging to zinc, though in a less eminent degree; a circumstance which has induced Malouin to represent that semi-metal as nearly allied to tin.

This noise seems to be owing to the separation or sudden division of the parts of the metal; and it seems to indicate a fracture; though tin, as we have already mentioned, makes scarce any resistance to a force directed to bend it.

Tin is the lightest of all metals. It is so soft that it may be marked with the nail. In water, it loses about a seventh part of its weight. It has a very discernible smell; and when it is rubbed, that property becomes still more eminent. It has a disagreeable taste, peculiar

liar to itself; which is even so strong, that some physicians ascribe to this metal a pretty strong power of action on the animal œconomy, and have recommended it for several diseases. Being so excessively soft, it is scarcely sonorous. Tin holds the second place among metals, arranged according to their ductility; under the hammer it is reducible into plates thinner than leaves of paper, which are of great use in various arts. It is so tenacious that a tin thread, one-tenth of an inch in diameter, will sustain without breaking a weight of forty-nine pounds and an half. M. Mongez could not accomplish the crystallization of tin. M. de la Chenaye, a gentleman who studied under me, has effected it by melting the metal for several times successively. By this means he has obtained a rhomboidal assemblage of prisms or needles joined longitudinally.

Most mineralogists still doubt the existence of native tin. Several authors, however, assert, that it is found in Saxony, in Bohemia, and in Malacca. It even appears to be a sufficiently attested fact, that there is native tin in the tin mines of Cornwall: and M. Sage has described a specimen which he received from Mr Woulfe, a London chemist. The fracture of that piece is grey and sparkling; when beaten on the anvil, it forms brilliant and flexible plates of tin. Tin is more commonly met with in a black oxide, ponderous, opaque, and crystallized in octohædrons, or pyramids with four faces. The texture of this ore is sparry and lamellated. Bucquet thinks it to be a true carbonate of tin. M. Sage is of opinion that these crystals are mineralized by the muriatic acid. We may here recollect, that most of the white tin crystals in cabinets of natural history are native tunstate of lime, which

which ought not to be confounded with oxide of tin, as the oxide does not become yellow when brought into contact with acids.

Those matters which are denominated tin ores, are of a very deep red, violet, or black colour, and their specific gravity is greater than that of any other mineral substance. Those ores are sometimes crystallized in irregular cubes; and they are then dispersed in groupes in a gangue of quartz or fusible spar. They are often in masses, not crystallized. Almost all naturalists agree in considering coloured tin ores as combinations of tin with arsenic, and ascribe their uncommon ponderosity to the want of sulphur. Messrs Sage and Kirwan, however, think they contain no arsenic; and the former of these gentlemen affirms that they need not to be roasted, unless they be mixed with arsenical pyrites; which is very common. Mr Kirwan says, black tin ore contains $\frac{80}{100}$ of tin and iron.

Bergman has found sulphureous tin in nature among the minerals of Siberia. The specimen of that sulphureous ore which he examined, was externally of a golden colour, resembling *aurum musivum*: within, it exhibited a mass of radiated crystals, white, sparkling, brittle, and changing its colour when exposed to the air. He found it to contain a little copper.

We know of no tin ores any where in France. M. Baumé, however, suspects that such ores might be found in the neighbourhood of Alençon, and in some of the districts of Brittany, because there are rock crystals found there which appear to be coloured with this metal. The places where these ores abound, and are wrought in mines, are the counties of Cornwall and Devonshire in England, Germany, Bohemia, Saxony, the island of Banca, and the peninsula of Malacca
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in the East Indies. Many naturalists consider garnets as a kind of tin ore, on account no doubt of their colour. They differ from tin ores, however, in transparency and in gravity; for they are much lighter. Besides, Messrs Bucquet and Sage could find no tin in them.

Tin exists in nature but in a few different states, which may be all reduced to the following varieties.

Varieties.

1. Native tin in leaves or plates.
2. White sparry tin ore, in octohædral crystals.
3. Tin ore, of a yellowish white colour, often coloured and semi-transparent, like topazes.
4. Brown, reddish tin ore, in cubic crystals, more or less regular.
5. Tin stone, Swedish *tinberg*. This is a stone or sand, containing a mixture of oxide of tin; it is grey, blue, brown, or black.
6. Sulphureous tin ore, of a bright colour, resembling zinc, or gilded over like *aureum musivum*.

In assaying tin ore, it must first be broken into lumps, then coarsely pounded, washed, and roasted in a covered earthen capsule, in order that as little tin as possible may be lost, care being taken, however, to uncover it from time to time; for as Cramer has remarked, a good deal of the metal is lost when it is roasted in a vessel constantly open. It must likewise be quickly roasted, that the tin may not be too much oxidated. M. Baumé proposes to obviate these inconveniences

conveniences by adding a portion of pitch, which reduces a part of the oxide formed in this operation. After the ore is roasted, it is to be quickly melted in a crucible, with three parts of black flux and a little decrepitated marine salt. By comparing the three weights of the washed ore, the roasted ore, and the metallic button, it may be estimated what quantity of extraneous matters the ore contains, and what quantity of tin it will yield in the hundred weight. Cramer proposes a more expeditious way of making this assay,—by which, too, less of the ore is likely to be lost,—by using two large pieces of charcoal burnt from linden or hazel wood. In one of these there must be a cavity to contain the tin ore with the pitch, instead of a crucible; the other must be pierced with a small hole through which the vapours may escape. The latter of these covers the former; and they must first be luted, and afterwards bound together with iron wire. They are then set on fire before the nozzle of a forge bellows, and kept up against it by other pieces of coal placed around them. After they have got enough of the fire to melt the tin, they are quenched with water, and the tin is found in a metallic button.

Bergman proposes to assay tin ores by dissolving them in sulphuric acid; mixing that with muriatic acid, and precipitating the mixture with fixed alkali. When the tin is pure, 131 grains of this precipitate are equal to 106 grains of tin. If it be mixed with copper and iron, these extraneous metals are separated by the nitric and the muriatic acid.

The working of tin ores in the great way resembles the foregoing process. It is often necessary to make fires of wood in the mines, to calcine and soften the gangue, which is very hard. These fires disengage vapours that

are very noxious. This process is followed at the hills of Geyer. At other times those ores are found in sand, at no great depth beneath the surface of the earth, as at Eiberstock. The ore is there pounded, and washed in boxes with small partitions of cloth to retain the metallic particles. It is then roasted in reverberating furnaces, with horizontal chimnies fitted to them, to collect the sulphur and arsenic. It is then melted in a furnace with a sleeve furnace, and poured into moulds which give it the form of blocks. In Germany and England tin ores are wrought nearly in the same way. In England, according to Geoffroy, the metal is always alloyed with lead and copper, and never exported pure. There comes too from England a statuetical tin, which is called *tin in tears*, and is thought to be very pure; but Messrs Bayen and Charlard affirm, that it is sometimes mixed with copper. The hardest tin of all is that which comes from Malacca and Banca. Malacca tin appears to have been run into moulds, which have given it the form of a truncated quadrangular pyramid, with a thin border round its base: this is said to be in hats or standishes: Each piece weighs about a pound. The tin of Banca is in oblong ingots of about forty-five or fifty pounds. Both these kinds of tin are covered with a dirty grey rust more or less thick.

The tin which we get from England, and which being cheaper, is much more used than pure Indian tin, is in large blocks, each weighing about three hundred pounds. It is alloyed with copper, either artificially, as Geoffroy tells us, or naturally, according to the Baron de Dietrich. That it may be more easily retailed, it is afterwards melted into small in-

gots

gots or sticks, about nine or ten inches in circumference, and a foot and an half long *.

When tin is exposed to fire in close vessels, it melts very quickly. It is the most fusible of all metals. If the fire be not increased it remains fixed ; but its fixity appears to be only relative ; for when exposed to a considerable heat it is volatilized, as we are just about to relate. If heated in contact with air, there appears on its surface as soon as it is melted a dirty grey pellicle, which contracts into a shrivelled form. On taking it off, we behold the tin beneath, with its proper metallic lustre, and not adhering to the pellicle : but it loses this appearance, and a new pellicle is formed. The whole quantity of tin in fusion may be in this manner carried off in pellicles, which are nothing but the oxide of the metal, or a combination of the metal with the oxigène of the atmosphere. Tin, when reduced to oxide, becomes one-tenth heavier. When this metal is made red hot, Geoffroy has observed, that its oxide is gradually sublimated by a very lively whitish flame, which he compares to the flame of zinc. This is actually an inflammation or rapid combustion of the metal : and the volatilized tin arises at the same time in a light smoke, which condenses on cold bodies to a whitish oxide of tin in needles. The grey oxide of tin becomes white on being again exposed to the action of fire ; it then unites with a new portion of oxigène, and is more completely calcined. In this state it is called *tin-putty*. When exposed to a very intense

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heat,

* It is not true that tin is never exported pure from England : But however pure it may be exported, foreign tin-founders usually take care to alloy it, and ascribe the alloy to the English. Neumann tells, that the Dutch keep English stamps for the purpose.

heat, like that of a porcelain furnace, it melts into a glass. Messrs Macquer and Baumé have observed, on treating tin in this way in a crucible, that a part of it was changed into a white, needled oxide; while another part under the former was hard, reddish, and half melted; a third was converted into ruby or hyacinth-coloured glass; and, lastly, there remained in the bottom of the crucible a portion of the tin in its metallic state. Notwithstanding of this, oxide of tin is still considered as infusible; and it is at least the most refractory of all oxides. This oxide may be decomposed with the help of combustible animal or vegetable matters; which by detaching the oxigene enable the metal to resume all its properties. It appears, however, that *tin putty*, when thoroughly calcined, retains, with no inconsiderable force, the oxigene with which it is united; for to reduce it is very difficult, and a great quantity of combustible matters must be employed for the purpose. This has led M. Baumé and several other chemists to think, that when tin ores are too much roasted, a part is so changed as to be no longer susceptible of reduction.

Tin does not suffer much alteration from air; when very pure, it is scarce liable even to lose its lustre. That which commonly passes in commerce is at length covered over with a grey dust; but this dust, according to Macquer, never penetrates deeper than the surface, as the rust of iron does.

Water does not dissolve or calcine tin; yet a piece of tin exposed to the action of water is at length tarnished, and seemingly calcined on its surface.

Earthy matters never contract any union with this metal; its oxide being so very infusible, never forms either transparent or coloured glass with vitrifiable substances.

stances. But as it is so very white, it is capable of interposing itself among the particles of glass, so as to render it very opaque, and of a dead white colour. This sort of vitreous frit is called *enamel*. The infusibility of tin putty enables it to destroy the transparency of any kind of glass, and convert it into a coloured enamel.

We know not in what manner lime, magnesia, or alkalis act upon tin: but there can be no doubt that alkalis, with the help of water, may effect some alteration on this metal; for they in a very short time cause it to assume the colours of the rainbow.

According to Kunckel, the concentrated sulphuric acid dissolves half its weight of tin; heat favours this solution. A very pungent sulphureous gas is disengaged from the matters, without any very discernible emotion or effervescence. In this operation, the tin seizes the oxigene of the sulphuric acid; it is quickly oxidated, and the acid retains so much of it as to afford a precipitate by water. The sulphuric acid, diluted in a little water, acts in the same manner on tin: but this solution is more permanent, and does not afford so copious a precipitate by water as the former. When the acid is very weak, it does not dissolve tin at all. In this combination the tin attracts so much oxigene from the sulphuric acid as to form sulphur very quickly. The sulphur communicates a brown colour to the solution when it is hot, and when it is cold subsides as a precipitate. Messrs Macquer and Baumé are convinced of the presence of sulphur in this combination. On continuing to heat the solution, the tin is precipitated in a white oxide. The same phænomenon will at length take place, even without the help of heat. The sulphuric solution of tin is very caustic. M. Monnet obtained

obtained from it by cooling, crystals resembling those of calcareous sulphate, or in fine needles intermixed and intertwined with one another. The oxide of tin precipitated from this solution by rest and heat, is soluble in the sulphuric acid. If the sulphuric solution of tin be evaporated to dryness, the oxide which it then affords is grey, scarce reducible, and not soluble in that acid. The alkalis precipitate tin dissolved in the sulphuric acid in a very white oxide.

Tin decomposes the nitric acid, even cold, with amazing rapidity. This is one of the most astonishingly rapid solutions in all chemistry. Tin appears to have a very strong tendency to combine with the oxygen of the nitric acid; and as the azotic principle does not adhere to the oxygenous with near the same obstinacy as the sulphur does in the sulphuric acid, it is not at all surprising that the nitric acid should be decomposed by tin in a much more rapid and lively manner than the sulphuric acid. M. de Morveau has observed, that in a solution of tin by the nitric acid, there was no gas disengaged, but there was a portion of ammoniac formed. It appears then, that not only the nitric acid, but the water, is decomposed by tin; for the ammoniac formed in this operation can only be formed by the union of the hydrogen of the water with the azote of the acid of nitre.

Tin is reduced into a white oxide, which Macquer ineffectually attempted to reduce to metal: this metal therefore appears to be supersaturated with oxygen. The nitric acid retains only a little of it in solution; and when it is evaporated with a view to obtain nitrate of tin in crystals, the tin which was dissolved in the acid is very soon precipitated, leaving the acid almost pure.

pure. Bucquet, however, asserts, that a very deliquescent nitre of tin may be obtained from this solution; but he has not determined its form. He asserts likewise, that on washing calx of tin formed by the decomposition of the nitric acid, the water dissolves a little nitrate of tin, which may be obtained from it by evaporation. The nitric acid retains a little more tin dissolved in it when it is diluted in a large proportion of water; but it precipitates the oxide which it has thus obtained either by heat or by rest. Messrs Bayen and Charlard, in their valuable experiments on tin, have discovered, that when the nitric acid is impregnated with as much tin as it can reduce to oxide, and made so thick with it as to be unfit for acting on any other metal; the mass, if copiously washed with distilled water, and evaporated to dryness, gives a *stanno-nitrous* salt, which detonizes by itself in a hot roasting pot, and burns with a white thick flame like that of phosphorus. Oxide of tin sufficiently lixiviated, affords by exsiccation a semi-transparent mass resembling scales. The *stanno-nitrous* salt, when distilled in a retort, swells, boils up in bubbles, and on a sudden fills the receiver with a white thick vapour of a nitrous smell.

The fuming muriatic acid acts with considerable strength on tin: it dissolves the metal with the help of heat, or even cold; but instantly loses its colour and the property of fuming. The faint effervescence which takes place on this occasion, disengages from the mixture an inflammable foetid gas, which, however, has no resemblance to the foetor of arsenic, notwithstanding what some chemists have pretended to the contrary. Water is therefore decomposed by tin, with the help of the muriatic acid. That acid dissolves in this process

more than half its own weight of tin. The solution is yellowish, has a very foetid smell, and affords not, like the preceding solutions of tin with acid, a precipitate of oxide of tin. When this solution is evaporated, it affords very regular brilliant needles, which attract a little moisture from the air. M. Monnet says that those needles, after falling into a deliquium, crystallize, and remain dry in the air. M. Baumé, who has prepared muriate of tin in the great way, with an hundred and fifty pounds of acid to twenty-five pounds of tin, for the manufacture of printed cloths, gives an accurate account of several of its properties. Of twelve pounds of tin dissolved in forty-eight pounds of muriatic acid, there remained two ounces and six drams in a grey powder; which did not dissolve in a pound of the acid, though digested in it for a number of days. Margraaf thinks it to be arsenic. M. Baumé has not examined it. He compares the smell of that solution concentrated to that of the black earths of old privies; and observes, that when it falls on the fingers, it is impossible, to wash or wipe away the metallic smell of tin which it communicates to them, but which goes off of itself in the course of four and-twenty hours. He observes, that the crystals of muriate of tin vary according to the state of the acid: Sometimes they are little white needles. From the same solution he obtained both white and rose-coloured needles. The rose-coloured, when purified by solution and evaporation, afforded, by cooling, large crystals nearly like those of sulphate of soda. At other times, employing the common muriatic acid, he obtained the salt in small pearl-white scales, like those of the boracid acid. He does not mention the action of fire on this salt. M. Monnet, who distilled the muriatic solution of tin, affirms, that

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be obtained from it a very fusible unctuous matter,—in short, a true butter of tin, and a fuming liquor like that of Libavius, which we shall hereafter mention. This fact agrees with what Macquer has observed concerning a solution of tin in the muriatic acid, which was almost entirely crystallized during winter, but became fluid again in summer; a property which is found to belong to sublimated muriate of tin. That illustrious chemist has observed, that after a number of years there was a white sediment formed in this solution. The combination of the muriatic acid with oxide of tin affords a much more copious precipitate than any of the other solutions of this metallic calx, by alkalis and lime. The alkalis again dissolve a part of the precipitated oxide, and assume a brown yellow colour. By dissolving large blocks of English tin, and in general all impure tin in this acid, Messrs Bayen and Charlard discovered at length that English tin contains some particles of arsenic. When tin contains arsenic, in proportion as the acid acts on the tin the metal assumes a black colour; and when it is totally dissolved, there remains a blackish powder; which is pure arsenic, or arsenic combined with a small portion of copper. This acid may therefore be employed to ascertain the presence of arsenic in tin, and determine its quantity.

The oxygenated muriatic acid dissolves tin very readily, and without any discernible effervescence; for the metal quickly absorbs the excess of oxigene in the acid, without decomposing the water in order to unite with the oxigene which it contains. This solution possesses of consequence all the properties of the foregoing solution.

The mixed nitro-muriatic acid, consisting of two parts of nitric acid and one of the muriatic, combines

with tin with effervescence. It produces a strong heat, which should be diminished by immersing the mixture in cold water. To compose a permanent solution of tin in this mixed acid, care must be taken to put the metal only by degrees into the acid, and to wait till the first portion be entirely dissolved before putting in a second. If a large quantity of the metal were put all at once into the acid, most of it would be oxidated. *Aqua-regia* is capable of dissolving and holding in solution half its weight of tin. This solution is of a reddish brown colour; but its colour is very faint: it often forms in a few moments a tremulous jelly, of the appearance of rosin. This substance becomes in a few days more solid; at the end of which time it may be cut like a firm animal jelly. Some portions of it exhibit the semi-transparency and whiteness of the opal. It exhales a poignant smell of muriatic acid; but this smell is not foetid like that of the muriatic solution of tin. I have preserved some of it for several years in a bottle but indifferently stopped, and it lost nothing of its transparency or solidity. In order that tin dissolved in *aqua-regia* may form a jelly, the solution must contain a good deal of the metallic oxide. Sometimes, on adding to it half its weight of water, it becomes concrete, though not so before. But this jelly, formed by the help of water, is of an opal colour; because, as has been remarked by Macquer, this solution being susceptible of decomposition by water, a portion of oxide is precipitated and destroys the transparency of the jelly. That skilful chemist has farther observed, that when the solution of tin in *aqua-regia* is heated, a lively effervescence takes place, owing to the re-action of the mixed acid on the metal, on which it still retains some power of acting. The solution then loses its colour,

pour, and becomes fixed by cooling. The jelly new formed is beautifully transparent. By rest, a liquid regaline solution of tin sometimes deposits small needle crystals. Neither these, nor the gas disengaged during the action of the nitro-muriatic acid on tin, have not yet been examined. Messrs Bayen and Charlard have found that this solvent might likewise be used to ascertain the presence of arsenic in tin; but that as it acts with considerable force on the semi-metal, it would not determine the quantity so precisely as the muriatic acid itself is capable of doing.

We know not in what manner the other acids act upon tin. All sulphuric neutral salts, especially sulphate of potash or soda, are liable to be decomposed by tin. By heating in a crucible equal parts of sulphate of potash and tin, I obtained a greenish melted mass, which had no metallic properties, but was a true stannic sulphure. Tin detaches the oxigene from the sulphuric acid. The sulphure separated by this decomposition combines with the potash; and that sulphure dissolves a portion of the oxide of tin. This is the third metallic substance which we have found to possess the property of decomposing alkaline sulphates. We will presently see that Glauber had taken notice of this fact in regard to ammoniacal sulphate.

This metal makes nitre detonize rapidly. It is melted and heated in a crucible till it assume a dark red colour, and the nitre then thrown on it in a powder. A white sparkling flame accompanies the detonation. When more nitre is added, the detonation no longer takes place, the tin being entirely reduced to oxide. The white powder which remains contains alkali rendered caustic by the oxide of tin, and even combined with a certain quantity of that oxide. On forming
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ing it into a lixivium, the tin may be precipitated by an acid. If the grey oxide of tin melt with nitre, as Geoffroy has observed, the reason of this must be its still containing a portion of tin not reduced to oxide; for when we take a perfect oxide of this metal, that for instance which has long been exposed to heat, and is very white, or rather that which owes its formation to acids; neither of these exhibits any such phenomenon.

Tin decomposes ammoniacal muriate very readily: a quantity of ammoniac, strongly caustic, and in a gaseous state, is disengaged. Bucquet, who made a series of experiments on the decomposition of ammoniacal salts by metallic matters and their oxides, observes, that a good deal of inflammable gas is disengaged by the reaction of tin on ammoniacal muriate. According to the experiments of that skilful chemist, metals decompose this salt in consequence of the muriatic acid acting upon them. As we have seen that the muriatic acid has a very considerable affinity with tin, we may conclude Bucquet's theory to be satisfactory and consistent with facts. Glauber gave out, that his secret ammoniacal salt, or ammoniacal sulphate, was decomposed by tin; but according to Pott, who repeated Glauber's experiment, the decomposition is not complete, doubtless because the sulphuric has not so strong a tendency as the muriatic acid to combine with tin. Bucquet likewise observes, that as tin is very fusible, it gathers into a button at the bottom of the retort; and that the ammoniacal muriate of consequence is not so completely decomposed by the metal as it might otherwise be. This is the reason why tin does not decompose this salt so completely as the less fusible metals. The residue of this decomposition is solid muriate of tin, decomposable by water, and resembling that formed by corrosive muriate of

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of mercury with this metal ; of which we will hereafter speak.

Tin may be easily combined with sulphur by casting one or two parts of this combustible matter in powder upon five or six parts of tin melted in an iron ladle : this mixture, being stirred with an iron spatula, becomes black and kindles. When melted in a crucible, it forms a brittle mass in flat bundled needles. This composition is much more difficult to melt than tin ; and in the same manner all soft fusible metals are less easily melted when mixed with sulphur than when pure. But it is worthy of our notice, that though tin may be alloyed with sulphur, yet this mixture is never found in nature. With zinc the case is directly opposite ; for though in nature it be often found combined with sulphur, yet in the laboratory we find it exceedingly difficult to effect such an union. Nature often differs greatly in her operations from art : but if she sometimes effect combinations which art cannot imitate, art also forms combinations of which nature displays no pattern.

Arsenic scarce unites with tin by fusion ; being mostly dissipated by volatilization on such an occasion. Arseniate of potash combines better with this metal ; and M. Baumé has observed, that in this combination a part of the acid of arsenic forsakes the alkali, in order to unite with the tin, to which it yields a part of its oxigene, and the result is a brittle and very brilliant button with facets like antimony. Margraf's experiments on the union of tin with oxide of arsenic by distillation, show, that a part of that oxide is reduced to arsenic, while, again, so much of the tin is oxidated : that when tin is once united with arsenic, it cannot be again separated from it even by the most violent action of fire ; and that tin probably retains always a certain portion of arsenic,
which

which may render it dangerous in kitchen uses. By distilling oxide of tin impregnated with arsenic, Margraf obtained a liquor of a phosphoric smell. Messrs Bayen and Charlard have since examined the combination of arsenic with tin. They have observed, that the oxide of arsenic, simply called *white arsenic*, cannot combine with tin unless it be reduced to the metallic state; and that the combination may be much better effected by a direct combination of *regulus* of arsenic with tin. If you put into a retort three ounces six drachms of tin, with two drachms of *regulus* of arsenic in coarse powder, and after fitting a receiver to the retort, make it red hot, nearly two grains of arsenic rise into the neck of the retort, and a metallic button, four ounces in weight, is found in its bottom. This mixture, which contains one sixteenth of arsenic, is crystallized in large facets like bismuth. It is more brittle than zinc, and more difficult to melt than tin. It becomes soft at first; and if it be touched while in this state with an iron rod, a sound is heard, produced by the friction of the plates against one another. It melts into a clammy paste; and the arsenic goes then gradually off in a smoke.

Cobalt unites with tin by fusion, forming a mixture with fine grains closely united, and of a light violet colour.

Tin and bismuth form, according to Gellert, a brittle mixture with cubic facets. Workers in tin sometimes mix it with bismuth to render it white and hard. As it renders it much harder, and is dearer than zinc, which produces the same effects on tin, the workmen employ it only in the proportion of a pound, or a pound and an half of bismuth to the hundred weight of tin: and we have nothing from its effect on the animal œconomy; effects which the strong analogy between lead and bismuth in all their properties might move us to fear, as likely to be

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no less fatal than those of that metal. Bismuth may be separated from tin with the help of the muriatic acid; which dissolves the tin, leaving the bismuth separate in the form of a white powder, provided the weak muriatic acid be employed. The nitro-muriatic acid, when diluted in water, produces the same effects.

Antimony combined with tin forms, according to Gellert, a very brittle white metal; the specific gravity of which is less than that of the two metallic substances taken separately.

Zinc is easily combined with tin; and the result is a hard metal with small grains closely united; and the more ductile in proportion as the quantity of the tin is greater.

Cronstedt asserts, that nickel combined with tin forms a white brilliant mass; which, when calcined under a muffle, ascends in the form of a vegetating substance.

Mercury dissolves tin in any proportion with the greatest facility. This combination is effected by pouring hot mercury into melted tin. The solidity of the amalgam thus produced varies with the proportions of the two metallic substances. Formerly there was an amalgam composed of four parts of tin and one of mercury, and run into balls, which, when they cooled, became solid. Those balls were suspended in water to purify it. The water was at the same time boiled; and the precipitation of the extraneous matter which altered it was entirely owing to ebullition. This amalgam of tin is susceptible of crystallization. It forms little square crystals, as M. Daubenton has observed of the amalgam of tin, which he used for stopping the mouths of vessels containing preparations in the King's garden. Sage says, these crystals are grey and sparkling, in foliated plates, thinner

thinner at the edges than in the middle, and the interstices among them polygon figures.

Tin having a greater affinity than mercury with oxygen, decomposes corrosive mercurial muriate. To effect this decomposition, the tin is first divided by means of a little mercury: equal parts of this amalgam and corrosive mercurial muriate are then triturated together; and the mixture is distilled in a glass retort by a very moderate heat. There passes first into the receiver a colourless liquor; soon after this is followed by thick white vapour, which is forced up with a sort of explosion, and covers the sides of the receiver with a very thin layer. This vapour is condensed into a thick, white, and very copious smoke, known by the name of *Libavius's fuming liquor*. It is a combination of the muriatic acid with tin, in which the acid appears to become supersaturated with oxygen. This liquor, when inclosed in a phial, does not diffuse any visible vapour. There is, however, a certain quantity disengaged from it, which deposits oxide of tin in needle crystals on the upper part of the phial; so that in a few months the lower end of the neck is entirely closed up. A little of this oxide is likewise precipitated to the bottom of the liquor in unequal leaves. Its smell is very pungent, and makes a person sneeze. Its vapours are not visible except when in contact with the air. They seem to consist of a gas of a peculiar nature, which is decomposable by air; and on coming into contact with air yields a precipitate of oxide of tin, in the same manner as the fluoric acid gas affords, on coming into contact with water, a precipitate of siliceous earth, and as sulphurated hydrogenous gas deposits sulphur when exposed to the contact of air. Can this be a combination of oxygenated muriatic acid gas with oxide of tin?

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Water does not produce any discernible precipitate in *Libavius's fuming liquor*: but it appears to operate upon it a decomposition which has not yet been properly examined. When a quantity of this liquor, newly prepared, is poured into distilled water, it produces a kind of hissing like that which the sulphuric acid, highly concentrated, produces when mixed with water. It appears to separate into a great many small particles, which are transparent and irregular, and seem to have no adhesion to the water. On a near observation of what passes when this mixture is made, bubbles are perceived rising from these particles to the surface of the water, where they are reduced to vapour, which is rendered white by the contact of air. When the water is stirred those particles are quickly dissolved; and the solution ceases to exhale vapour. Macquer affirms, that when this fuming liquor is diluted in a large quantity of water, it precipitates an oxide in light white flakes.

The gas of the fuming liquor is scarce elastic. It never pushes out the stopper of the phial in which it is confined; as the nitric and the muriatic acids, ammoniac, and æther, &c. do.

M. Adet, who has read to the Academy a memoir on the *fuming liquor of Libavius*, has observed, 1. That the effervescence which takes place whenever it is mixed with water, depends on the disengagement of an elastic fluid possessing all the properties of azotic gas: 2. That the fuming liquor, combined with water in the proportion of 7 to 22, forms a solid body which is melted by heat and congealed by cold, and appears to be subject to the same laws as oxygenated muriate of tin, or butter of tin. From his several experiments he concludes the fuming liquor to be nothing but a com-

pound of muriatic acid in the æriform state, with oxide of tin having an excess of oxigene. This salt, he thinks, bears the same relation to common muriate of tin which oxygenated muriate of mercury bears to common muriate of mercury, or *mercurius dulcis*.

The residue which remains after the distillation of the *fuming liquor of Libavius* exhibits as many interesting phænomena as the liquor itself. The upper part and the neck of the retort are coated with a thin white or grey crust; which, according to the experiments of Rouelle the younger, contains a little of the *fuming liquor*, concrete muriate of tin, or corneous tin, mild mercurial muriate, and running mercury. The bottom of the vessel displays an amalgam of mercury and tin, above which there is a little *corneous tin* of a grey white colour, solid and compact, and susceptible of volatilization by a stronger heat. If this substance be put into a retort it melts, and divides into two strata; the inferior stratum black, and the superior white, and like the former, *corneous tin*. Rouelle appears to suspect, that these two substances, thus different from each other and refusing to mix, are owing to an alloy contained in the tin. According to that ingenious chemist, the more this metal is alloyed, the less *fuming liquor* does it afford. Solid muriate of tin attracts the moisture of the atmosphere, and is very readily dissolved in water. M. Baumé has advanced a theory concerning the combination of tin with the muriatic acid, which is nearly the same with what Scheele and Bergman have advanced concerning what they call *dephlogisticated marine acid*. He thinks that in this operation the acid loses its *phlogiston*, as those chemists thought it did when distilled on oxide of manganese. He imagines that this acid might be obtained perfectly pure by a distillation of the

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fuming liquor of Libavius; from which it appears, that he considers the common muriatic acid as supersaturated with *phlogiston*. M. Baumé was therefore prior to Scheele in the discovery of the two states of the muriatic acid; but he has not described the singular properties which that acid possesses when oxygenated, as has been done by the celebrated Swedish chemist.

The uses of tin are very many. It is employed in a great number of the arts. It is used for lining a great many vessels, for organ pipes, for decorations, &c. An amalgam of tin is employed for silvering glasses. Copper-smiths tin copper by running a mixture of tin and lead upon it: A mixture of tin with copper is used for bells and statues of bronze. Tin workers mix it with bismuth, antimony, lead, and copper for utensils of all kinds; which are very liable to alteration by the action of air. Tin putty is used in polishing hard bodies. It is melted with oxide of lead and sand for enamel, as well as for glazing earthen ware, &c. Crystallized muriate of tin is used in printing cloth; a solution of this salt in *aqua regia*, or the nitro-muriatic acid, improves the dye of cochineal, gum lac, &c. so as to convert it to a lively fire colour. Dyers use this solution, calling it a *composition* for dyeing scarlet. When mixed on a bath with the above-mentioned dyeing stuffs, it produces a precipitate which carries off the colouring particles, and fixes them on the cloth. We owe this observation to Macquer, whose labours have been very beneficial to the art of dyeing.

Some chemists have considered tin as very dangerous when used for kitchen utensils. Navier, in his work on counterpoisons, &c. relates, that a number of persons have been poisoned by *ragouts*, in which tin-spoons had been suffered to stand for a while, and by sugar kept in tin

cannisters. These unhappy effects are usually ascribed to the arsenic, which Geoffroy in 1738 asserted that he had found to exist in tin, and which Margraf thought he found in the purest tins, and in no inconsiderable quantity.

But the fears thus excited have been dispelled by the experiments of Messrs Bayen and Charlard, of which we have already had occasion to take notice in the history of this metal. Those chemists have proved by the most decisive experiments, 1. That the arsenic obtained by Margraf from the tin of Morlaix, amounting to nearly six and thirty grains to an half ounce of tin, would have been much more than sufficient to destroy the known softness and flexibility of the metal, and render it as brittle as zinc. 2. That the tins of Banca and Malacca contain not a particle of that dangerous semi-metal. 3. That large blocks of English tin, when exposed to the action of the muriatic acid, afford a small quantity of a blackish powder, which is generally mixed with copper and arsenic; the arsenic, however, never amounting to more than three-fourths of a grain to the ounce of tin, and being often under that proportion. 4. That this small proportion of arsenic is rendered still less by the tin workers, who usually mix English tin with the purer tins of Malacca or Banca. 5. That arsenic by combination with tin loses a part of its properties and of its corrosive powers. 6. Lastly, That the very small quantity of alloyed tin which enters into the aliments prepared in tin-vessels, cannot possibly have any influence on the animal œconomy; for, from the most accurate calculation of the loss suffered by a tin-plate in two year's wear, it was found to have lost not more than three grains a month; and of consequence $\frac{1}{1765}$ of a grain of arsenic a day, supposing the tin

tin work of Paris to contain as much of that poisonous semi-metal as the tin-plate of London manufacture, on which M. Bayen made this observation.

We may observe, that if the chemists of Paris do not quite agree with Margraf, the difference may be occasioned by the difference between the Saxon tin on which his experiments were made, and the Indian and English tins which they have examined.

Farther, many physicians who had studied the medical powers of metallic matters had before pronounced tin perfectly harmless, and had even recommended the giving it in filings for disorders affecting the liver, or the matrix, and for worms. Schulz, in his dissertation on the use of metal vessels in preparing aliments and medicines, thinks tin, when very pure, to be very safe. La Poterie uses oxide of tin in preparing a medicine which he calls *anti-hectic*, and which is nothing but a lixivium of oxide of antimony and oxide of tin formed by the detonation of nitre.

Tin has been recommended as a vermifuge. At Edinburgh large dozes of it have been administered without success. Some country people are in use to leave sweet wine standing for four and twenty hours in a tin vessel, and to give that liquor by glasses to their children for the worms. Navier saw a girl of the age of fifteen or sixteen discharge by stool fifteen or sixteen large worms in a few hours after drinking a preparation of this kind. This medicine acts, therefore, as a violent purgative.

C H A P. XII.

Of Lead.

LEAD is an imperfect metal of a dark white colour, inclining somewhat to blue. The alchemists gave it the name of *Saturn*, because, as we will afterwards see, it absorbs and devours, so to speak, all other imperfect metals in its scorification. It is the least ductile, the least sonorous, and the least elastic of all metals. It may be hammered into thin plates: it is rendered very little harder by this operation. There is no metallic matter less tenacious than lead, a leaden thread $\frac{1}{16}$ of an inch in diameter cannot sustain more than $29\frac{1}{2}$ pounds weight without breaking. In gravity it is the third metallic substance. A cubic foot of lead weighs 828 pounds: in water it loses between $\frac{1}{11}$ and $\frac{1}{12}$ part of its weight: it is so very soft that it may be easily cut with a knife. It has a very discernible peculiar smell, which becomes still more discernible when it is rubbed: its taste is scarce sensible to the palate, but irritates the nerves of the stomach and the intestines, so as to produce, first pains and convulsions, and at length stupor and

and palsy. It may be caused to assume a regular form. The Abbé Mongez obtained it in quadrangular pyramids lying on their sides in such a form that one of the four sides was always much larger than the other three. Each pyramid consists of strata, or zones of other smaller pyramids, terminating generally in one common acute pyramid.

Lead is scarce ever found pure in the earth. Wallerius and Linnæus admit its existence in that state; which is denied, however, by Messrs Cronstedt, Justi, Monnet, &c. It is most commonly in an earthy, saline state, or mixed with sulphur, so as to form what is called *Galena*. Lead mines are generally at a great depth under ground; and are situated either in hills or in plains. Naturalists have distinguished a great many species of lead ore. The following are those most worthy of notice.

1. Native oxide of lead. This must not be confounded with *sparry lead* which contains carbonic acid. This oxide does not effervesce with the nitric acid. It is usually in white or grey ponderous solid masses, perhaps mixed with clay, sand, and chalk. The colour of the clay, according as it is more or less ferruginous, gains it the name of native *massicot*, or *minium*, or yellow and red oxide. Native ceruse of lead is often met with on the surface of galenas.

2. Carbonate of lead, or oxide of lead combined with the carbonic acid. This ore varies greatly in colour: it is either white, black, brown, yellow, or green, according to the state of the iron by which it is altered. It bears the general name of *sparry lead*, its contexture and crystallization being the same with those of certain spars. It effervesces with the nitric acid, which

disengages the carbonic acid it contains. This species is distinguished into the following varieties.

Varieties.

A. *White sparry lead.* This is carbonate of lead slowly deposited in crystals by waters. This lead is sometimes semi-transparent like spar. Its crystals are usually truncated hexahædral prisms, or striated cylindric columns, which appear to consist of a great number of filaments, or very slender small needles. Some specimens of this kind of lead are of a sparkling white colour like *filky gypsum*. There are others of a yellowish white colour. There are generally some of these prisms fistulous. White sparry lead is very plentiful in Low Brittany in the mines of Huelgoet and Poullaouen. M. Sage gave out, that white lead was mineralized by the muriatic acid. M. Laborié has affirmed it to be only a pure oxide of lead combined with fixed air, or carbonic acid, and mineralized by water. The Academy of Sciences at Paris having caused the experiments of both these chemists to be repeated, have adopted the opinion of M. Laborié; and Macquer has given it in his dictionary under the article *lead ores*. Sparry lead is always found in the same places with galena; and appears to be nothing but galena that has lost its sulphur, and of which the lead has been oxidated; for it is not uncommon to find galena beginning to pass into the state of white lead; as has been very well observed by M. Romé de Lille.

B. Some naturalists admit the existence of black lead; that is, white lead altered by a sulphureous

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reous vapour, and reduced to the metallic state: it may be considered as possessing a kind of middle nature between white lead and galena. It is crystallized in irregular masses.

C. Green sparry lead. This mineral is more or less of a transparent green, most frequently yellowish, and always mixed with ochre and earthy iron. Sometimes it has no regular form, but resembles a kind of moss. Of this kind are most of the specimens from Hofsgrund, near Friburgh, in Brisgaw. Green lead is commonly crystallized in hexahædral prisms, either truncated, or terminating in hexahædral pyramids entire, or truncated near the base. A good deal of it is found at Sainte-Marie-aux-Mines, and at Tschoppau in Saxony. It has been proved that lead owes its green colour to a mixture of iron, as iron is always found in the ores of this metal.

D. Reddish sparry lead of the colour of peach flowers. M. Mongez has found this variety crystallized like white sparry lead in the mines of Huelgoet.

E. Yellow sparry lead. This variety, which is crystallized in transparent hexahædral plates, has been known only for these few years: the plates are from half a line to four or five lines in diameter: they resemble glass of lead.

3. M. Monnet has discovered among lead ores some of the metal combined with the sulphuric acid. It is commonly in a white mass, soluble in eighteen parts of water: it is sometimes blackish and crystallized in very long striæ, or friable stalactites. This last variety effloresces

floresces in the air, and changes into a real sulphate of lead. On account of this property, M. Monnet calls it *pyritous ore of lead*. Dr Withering says, there is in the isle of Anglesey a great quantity of lead and iron mineralized together by the sulphuric acid.

4. Lead ore appears to be combined with the arsenic acid in the red lead ore of Siberia; which was first described by M. Lehman in the year 1766. This ore is of a very fine red colour, and its dust resembles carmine powder. It is often crystallized in rhomboidal tetrahedral prisms, which are short and obliquely truncated. M. Mongez, who thinks arsenic to be in the state of acid in all red ores, has discovered another ore of a greenish yellow colour, which comes from Siberia, and like the last mentioned contains arsenic.

5. M. Gahn has recognized the existence of the phosphoric acid in a greenish lead ore: this ore is sometimes, too, yellow and reddish; and on dissolving it in the nitric acid, and precipitating the oxide of lead by the sulphuric acid, the phosphoric acid is obtained by evaporating the supernatant liquor. Messrs la Metherie and Tenant at Paris have confirmed Gahn's analysis. M. de Laumont has written a memoir on native phosphate of lead, which is very plenteous in Brittany.

6. Lead is oftenest found in combination with sulphur: This ore bears the name of *galena*; in commerce it is also called *alquifoux*. This sulphure of lead generally consists of plates having nearly the colour and aspect of lead; but more brilliant and very brittle. There are a great many distinct varieties of galena; namely:

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Varieties.

- A. Cubic Galena. Its cubes are of various sizes, and either insulated or in groupes. It is often found with truncated angles. It is common at Freyberg.
- B. Massy Galena. This is in masses without any regular configuration. It abounds at Sainte Marie.
- C. Galena with large facets. It appears not to form regular crystals, but is entirely composed of large plates.
- D. Galena with small facets. This galena appears to consist like mica of small and very bright white scales. It is called *white silver ore*, on account of its containing a large proportion of that metal. Of this kind is the galena of the mines of Pompéan in Brittany.
- E. Galena with small grains, so called because its grains are very close : this ore is likewise very rich in silver, and is found along with the last mentioned ore. Galenas in general contain silver: We know of none which does not contain silver but the galena of Carinthia. But it has been observed, that the galena with the smallest facets and closest grains affords most silver. It would appear, that silver being in some manner unfit for entering into the combination of galena, of consequence deranges the regularity of its crystallization when it happens to enter into it.
- F. Galena crystallized like sparry lead in hexagonal prisms, or cylindric columns. It is found, as well as the last mentioned ore, in the mines of Huelgoet in Low Brittany. It is not rich in silver.

Varieties.

silver, and appears to be only spathose lead mineralized without having lost its form. In fact we sometimes observe in the same piece crystals of pure sparry lead entirely covered with very fine galena, and others entirely changed into galena through the anterior parts of the prisms. M. Romé de Lille is in possession of a number of such specimens. I have in my own cabinet a specimen of white lead ore, the base of whose prisms is absolutely in the state of galena, and which displays the change of which I am speaking.

Galena is generally found between two borders of blackish ochraceous quartz containing a good deal of silver, though that metal be not at the first observable. M. de Dolomieu, to whom we owe the observation of this fact, conjectures, that the lead might be at first mixed with this silver; and that the water carrying off the imperfect metal left the finer metal in the gangue. M. Monnet has discovered, that many galenas effloresce like pyrites. He tells us, that he obtained true sulphate of lead by washing one of those ores, the surface of which was white, and bore the appearance of an efflorescence.

7. Lead is sometimes combined in nature with sulphur, antimony, and silver. This ore is called *antimoniated galena*, and is of a needled striated structure like antimony: the presence of the semi-metal is known by the ascension of a white sublimate when the ore is calcined. It is found at Salberg and Sainte-Marie-aux-Mines.

8. There is another sort of galena, in which the lead is combined with sulphur, silver, and iron. This martial

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tial galena is harder and more solid than any of the foregoing. When scorified it affords yellow lead.

9. Lastly, Lead is often met with in oxide and galena mixed in sandy or calcareous earths and stones.

As almost all lead ores, and especially galenas, contain a considerable proportion of silver, it requires to be carefully assayed. For this purpose, after pounding and washing a certain quantity of the ore, it is carefully put in a pot, which must be covered to prevent it from flying out. Galena suffers little loss by roasting. After having undergone this operation, it is weighed and melted with three times its own weight of black flux, and a little decrepitated marine salt. The fixed alkali of the black flux absorbs the sulphur from the lead: the coal of tartar, which is another part of the same flux, serves to reduce the metal from the state of oxide, and the marine salt prevents the evaporation of a part of the metal contained in the crucible. After the melting, a button of lead is found in the crucible, and must be carefully weighed. The metallic button is in the next place *calcined*, and vitrified on a cupel, to separate the silver which it contains. The result of this assay is not entirely to be trusted to; for the alkali used as a flux forms with the sulphur of the galena *liver of sulphur*, or sulphure, which dissolves a portion of the lead. Besides, black flux is too expensive a reductive matter to be used in labours of this kind in the great way. It may therefore be proper to attempt the fusion of this ore on coals, in a reverberating furnace, either by itself, or with an addition of some cheap matters, such as iron and glass-gall, in a small proportion, to absorb the sulphur.

Bergman proposes the use of the nitric acid for assaying lead ores. That acid dissolves lead and oxide
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of iron, but produces no effect on sulphur. The solution is precipitated by carbonate of soda; and 132 grains of this precipitate are equal to 100 grains of lead in a metallic state. When the ore happens to contain silver, the oxide of silver is separated by ammoniac, which has the power of dissolving it.

At Pompéan, in working lead ore containing silver, after pounding it, and washing it with great care on tables, they carry it to the furnace, where they first roast it with a moderate heat, and afterwards melt it by increasing the fire. The melted lead is taken out of the furnace by a hole, which corresponds to one side of the hearth, and is stopped with clay during the operation. The lead is moulded into pigs; and now acquires the name of *wrought lead*. It contains silver. To separate the silver, the wrought lead is put into another furnace, the hearth of which is covered with ashes that have been lixiviated, sifted, and pressed down upon it. On one side of the hearth of this furnace there are two large bellows, and opposite to them two gutters, called *the passages of the litharge*. When the furnace becomes hot, the lead is oxidated; a part of it is evaporated and sublimated in small chimnies over the passages of the litharge: another portion of the metal is absorbed by the floor of the furnace; a third, and that the most considerable portion, is oxidated and partly vitrified; and this last portion receives the name of *litharge*. It is blown out of the furnace with the bellows; the action of which likewise contributes to the oxidation and vitrification of the lead, by pouring a copious stream of air on the metal when in fusion. When litharge has been calcined by a moderate fire, it is in a red scaly powder; it is then called *merchant's litharge*, because it is sold in this state, or *golden litharge*,

charge, on account of its colour. If it has been exposed to a stronger heat, it is then nearer a state of vitrification, and of a pale colour: and it now bears the name of *silver litharge*. Lastly, If the furnace be made very hot, the litharge is more completely melted, and runs into the form of irregular stalactites; it is now called *fresh litharge*. When the operation is finished, the silver which was contained in the lead remains in the former. This silver must be refined in small pieces, in order that it may throw off the lead which still remains among its particles.

Lead, after being oxidated in the refining, is again melted on coals, after which it contains but a very few particles of silver. It is now run into pigs and sold in this form. Sparry lead is melted among coals in the same way as the oxides.

When lead is exposed to fire, it melts long before becoming red hot. The heat requisite to maintain it in fusion is so slight, that a person may put his hand into melted lead without feeling any pain; and in that state it does not burn vegetable substances. It is scarce volatile; yet a very strong heat *will* volatilize it; and it then gives out smoke, and is reduced to vapour like the more fixed metals. If it be left to cool very slowly when melted; and if after a part becomes solid, what still remains fluid be decanted off; the solid part is found crystallized in quadrangular pyramids, the form of which we have already described.

Lead exposed to the contact of air while it melts, is covered with a grey dusky pellicle. This pellicle is carefully taken off, and reduced by agitation into a greenish grey powder, inclining to yellow. When this oxide is separated by a sieve from the grains of lead which are still intermixed with it, and again exposed to a more intense heat sufficient to make it red hot, it
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assumes a deep yellow colour. In this state it is called *massicot*. *Massicot*, slowly heated by a moderate fire, takes a beautiful red colour, and obtains the name of *minium*. If exposed to a strong heat, *massicot* melts into a glass, and does not afford any minium.

Lead, by being oxidated, gains an increase of weight nearly in the proportion of ten pounds to the hundred weight. This increase of weight which lead gains when reduced to oxide, and the circumstance of air's being necessary to this operation, led John Rey, a physician at Perigord, to conjecture, that air became fixed in this metal when it was *calcined*. Dr Priestley has confirmed John Rey's opinion by extracting vital air from minium. Oxide of lead, though very high coloured, may be entirely divested of its colour. Minium, if rather too much heated, becomes pale: when urged with fire, without having any other substance intermixed, it melts into a transparent glass, so fusible as to penetrate and make its way through all crucibles, notwithstanding whatever can be done to retain it. But a mixture of one part of sand with three parts of oxide of lead melts into a beautiful amber-coloured glass, the oxide contributing to the fusion of the sand. The tincture of that glass is fainter, and resembles the colour of topaz, when two parts of oxide of lead and one of sand or pulverized flint are melted together. A smaller quantity of oxide of lead added to common glass does not alter its transparency, but increases its specific gravity, and gives it a kind of unctuousness, which renders it easier to be cut and polished without breaking. This glass is the most proper for making achromatic lenses, but is very liable to be striated, and gelatinous in its appearance. The English call it *flint glass*. Our merchants have no small difficulty to find any large
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pieces without striæ in that which they import from England. This, which is a very considerable inconvenience, arises, as Macquer thinks, from the circumstance of the principles of the glass not combining uniformly together. To make them combine uniformly, it would be necessary to keep them long in fusion; but as the lead is volatilized, flint glass then loses part of its density, as well as that unctuousness which constitutes its peculiar value.

Although all the phenomena which attend the oxidation and vitrification of lead, show that it combines with the greatest facility, and in a very rapid manner with the base of pure air, or oxigene; yet it is among those metallic matters which have the least tendency to remain in combination with the oxigenous principle; for, as has been proved by Dr Priestley, it may be separated from it by the action of fire only. When minium is exposed to an intense heat in a retort, vital air is obtained from it, and a part of it is reduced to lead. All the oxides, and even glasses of lead, are easily decomposable by combustible matters: all that is necessary for this purpose is to mix them with charcoal, tallow, oils, resin, or in short any inflammable vegetable or animal substance; and to heat them till they afford a button of lead. This metal has therefore a weaker affinity than most other metallic substances with oxigene; and if it agrees with tin in some properties, in its oxidation and reduction it is subject to very different laws. These phenomena afford a new proof in favour of what we have advanced as one of the laws of the affinity of composition; namely, that we are not to judge of the affinity subsisting between any two bodies by the facility with which they combine,

but rather by the obstinacy with which they adhere together.

All the oxides of lead, and more especially minium, absorb a certain quantity of carbonic acid when exposed to the air. And in order therefore to preserve oxide of lead pure, it must be kept from the contact of air; or the carbonic acid, which it has absorbed from the air, may be separated by heating it before it be applied to any use.

Lead, when exposed to the air, is tarnished; and the more moist the air, the sooner does it produce this effect on the metal. A white dust is formed, and gradually carried off by the water; that white dust is not pure oxide of lead, but oxide of lead combined with carbonic acid absorbed from the atmosphere. The silver which is extracted from old lead that has been long exposed to the air, is produced in consequence of the lead not having been refined when it was first employed, and being in part oxidated by the action of the air of the atmosphere. The silver not having been separated from it at the first, has remained unaltered, and has even gradually increased in quantity as the imperfect metal has been destroyed by time.

Lead suffers no alteration from pure water; the metal does not separate the component principles of the fluid; yet the sides of leaden water-pipes are covered over with a whitish crust, or a kind of *ceruse*, the production of which is owing, no doubt, to the action of the various matters contained in the water upon the metallic substance. M. Luzuriaga says, that on shaking lead in grains, in a little water, in contact with air, the metal is speedily reduced to an oxide.

We know nothing of the action of salino-terreous substances and caustic alkalis on lead or its oxides.

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This metal is soluble in all the acids. The concentrated sulphuric acid acts upon it only when boiling; and it is likewise requisite that the lead be in thin plates. Sulphureous gas escapes during the re-action of the metal and the acid. When the acid is mostly decomposed, the mixture becomes white and dry; when washed with distilled water it separates into two portions. The most considerable of the two is insoluble in water: it consists of oxide of lead formed by the oxigene that the metal attracts from the sulphuric acid, which has at the same time given out a good deal of sulphureous gas. This oxide may be melted or reduced in the same way as that produced by the joint action of fire and air. The other portion, dissolved by the water, is a combination of the sulphuric acid with oxide of lead: this solution affords, when evaporated, small needles of sulphate of lead. M. Baumé and Bucquet have not described this salt as subsisting in any other form but this. M. Monnet has sometimes obtained it in short prismatic columns. M. Sage nearly agrees with M. Monnet, for he tells us, that sulphate of lead affords crystals in tetrahædral prisms. This salt is very caustic, at least 18 parts of water are requisite to dissolve it; it is decomposed by fire, lime, or alkalis.

The nitric acid appears to act very strongly on lead. When the acid is highly concentrated, and in no great quantity, the lead is speedily reduced to a white oxide with the oxigene, which is disengaged from the nitric acid at the same time when nitrous gas is disengaged. But if the acid is weaker and in greater quantity, less of it is decomposed, and there remains enough to dissolve the oxide of lead. As the solution is effected, there is a grey powder precipitated, which M. Grosse

took for mercury; but M. Baumé affirms it to be oxide of lead. I have many times, but still ineffectually, attempted to obtain mercury from it by sublimation, as also by urging it with fire sufficiently intense to reduce it to mercury if it were mercurial oxide. This solution gives no precipitate with water; by cooling, it affords crystals of a dead white colour, in a flat triangular form, with all their angles truncated. The same solution, subjected for several months to a slow evaporation, afforded crystals, the largest of which were about an inch in breadth, and their figure an hexahædral pyramid with three sides, alternately small and large, and its point truncated in such a manner as to render it a solid octagon. Rouelle has given a good description of this salt. Nitrate of lead decrepitates when exposed to fire, and melts with a yellowish flame when laid on a burning coal; the oxide of lead, which is at first yellow, is very speedily reduced to globules of lead. This salt is decomposable by lime and alkalis. The sulphuric acid, though it acts but very weakly on lead, has, however, a greater affinity than the nitric acid with the oxide of this metal. Pure sulphuric acid, or even an earthy or alkaline sulphate, poured into a nitric solution of lead, produces in a few moments a white precipitate. This precipitation takes place, because the sulphuric acid attracting the oxide of lead from the nitric acid, forms sulphate of lead, not very soluble, and similar to that which is prepared by an immediate combination of the sulphuric acid with this metal.

The pure muriatic acid, with the assistance of heat, is capable of oxidating lead, and dissolves a part of the oxide; but it is not easy to saturate it completely.

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This solution contains always an excess of the acid: by a strong evaporation, however, it affords fine, bright needled crystals, as has been observed by M. Monnet. Muriate of lead is somewhat, though but very little, liable to deliquiate. Lime and alkalis dissolve this, as well as the foregoing salts. This metal may be more readily and more intimately combined with the muriatic acid, by pouring the acid either free or combined with an alkaline or earthy base into a solution of nitrate of lead: A white precipitate, much more copious than that formed by the sulphuric acid, and resembling a coagulum, is instantly produced. This precipitate is a combination of oxide of lead with the muriatic acid, which has separated the metallic oxide from the nitric acid. This salt subsides to the bottom of the liquor, because it is much less soluble in water than nitrate of lead. If exposed to fire, it gives out vapours, and melts into a brown mass, called *corneous lead*, on account of the resemblance it bears to the silver which is distinguished by the same epithet. It dissolves well enough in thirty times its weight of boiling water. The solution of this salt when evaporated, crystallizes into small slender brilliant needles bundled together, or joined at one end under an obtuse angle. M. Sage says, this solution gives by very slow evaporation crystals in striated hexahedral prisms. The solution of corneous lead is decomposable by the sulphuric acid, which causes it to yield, like the nitric solution of lead, a white precipitate. This discovery was made by Grosse, and has been confirmed by M. Baumé, and all other chemists who have repeated the experiment. It contradicts the eighth column of Geoffroy's table, which represents lead as having a greater

affinity with the muriatic than with any of the other mineral acids.

All solutions of lead yield either black or brown precipitates when exposed to the action of earthy or alkaline sulphures; and the sulphur then unites with the oxide of lead to form a sort of galena: a circumstance which seems to indicate, that the lead exists in this ore in the state of oxide. In these operations there is a double decomposition, though not a double elective attraction; for the alkaline base of the sulphure is alone sufficient to decompose sulphate, nitrate, and muriate of lead.

All the oxides of lead are as easily decomposed in acids as lead itself; nay, often easier than the metal. In these solutions minium loses its colour. Lead does not act on sulphuric neutral salts, nor does it decompose sulphate of potash by heat, as tin, zinc, and antimony do.

Lead gives no sensible detonation with nitre. When the neutral salt is reduced to powder, and so cast on the metal in a state of fusion and a little red, scarce any motion of the matters, and no discernible flame, follows. However, the lead is oxidated and vitrified by the alkali of the nitre, and is found after the operation in small yellowish leaves like *litharge*.

Lead, with the help of heat, decomposes ammoniacal muriate very readily. This property is common to it with many other metals. Any oxide of lead, triturated cold with this salt, makes it give out ammoniacal gas. But, when this mixture is heated in a retort, the decomposition is very rapid. The ammoniac obtained, in consequence, is very caustic and poignant. Some chemists have advanced, that volatile alkali ex-
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tracted by *minium*, effervesces with acids, and have inferred that *minium* must therefore contain carbonic acid. Bucquet observed, that this effervescence was often owing to a portion of the ammoniac gas volatilized by the heat produced by the combination of the alkali with the acid; and that it did not take place when the acids employed were concentrated. He made one ingenious and very decisive experiment to determine this. Introducing into a bell-glass, over mercury, ammoniac obtained by *minium*, he conveyed into it a portion of sulphuric acid pretty strong, and sufficient to saturate the alkalis. At the instant when the two substances were mixed, an ebullition was produced, and a quantity of gas disengaged, and again rapidly absorbed, which was nothing but ammoniac gas. However, since it is acknowledged that oxides of lead, and particularly red lead or *minium*, contain carbonic acid, in consequence of having absorbed it from the atmosphere, it will be granted, that the ammoniac disengaged by those oxides must acquire a part of it. The mass remaining in the retort, after the decomposition of sal ammoniac by *minium*, is muriate of lead, which melts by a moderate heat into corneous lead, and may be totally dissolved in water. This is the melted mass which Margraff made use of in composing phosphorus of urine.

Hydrogenous gas alters lead in a very sensible manner; it colours its surface, and communicates to it changeable clouds, of the shades of the rainbow; it reduces oxide of lead. Minium, when brought into contact with this gas, becomes black, and takes the appearance of lead. Dr Priestley has observed, that a glass tube containing hydrogenous gas, and hermetically sealed, on being exposed for a number of days to the

heat of a sand-bath, becomes black within like foot, and a vacuum is at the same time formed, and drops of water are produced in the tube. This beautiful phenomenon is explained by considering that hydrogen has a greater affinity than lead with oxigene: a farther proof of which is, that this metal does not act at all upon water. English glass contains a good deal of oxide of lead: Hydrogenous gas, re-acting upon that oxide, gradually abstracts from it the oxigene which it contains, and combines with it to form water, while the lead regains its metallic colour.

Sulphur easily unites with this metal. When these two substances are melted together, the product is a sort of brittle mineral with facets, and of a deep grey sparkling colour. Sulphure of lead is very like *galena*, and is much more difficult to melt than lead. This phenomenon is peculiar to the combinations of the metals with sulphur. Very fusible metals become difficult to melt when mixed with sulphur; while again, such metals as are difficult to melt, become very fusible when united with this combustible matter.

We know nothing of the mixture of lead with arsenic. Neither nickel, manganese, cobalt, nor zinc, combines with this metal by fusion. Antimony forms a brittle mixture with lead, with small brilliant facets, in colour and contexture resembling iron or steel, according to the proportions in which the principles of the mixture are combined together; the specific gravity of this compound is greater than that of the two metallic substances taken separately.

Lead unites with bismuth, and forms by this combination a mixed metal of a fine close grain, and very brittle. Mercury dissolves lead with the greatest facility.

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cility. This amalgam is made up by pouring hot mercury into melted lead. It is white and sparkling, and in a certain space of time becomes solid: when triturated with amalgam of bismuth, it becomes as fluid as running mercury. It is a circumstance worthy of our notice, that this singular phænomenon takes place in the union of three metallic matters, which are very fusible, very ponderous, and more or less volatile.

Lead combines readily with tin by fusion. Two parts of lead and one of tin form a mixture more fusible than either of the two metals separate, and constitute the solder used by plumbers. Eight parts of bismuth, five of lead, and three of tin, form a mixture which is so fusible, that the heat of boiling water is sufficient to melt it, as M. d'Arcet has discovered.

As a mixture of lead and tin is applied to many ordinary and domestic uses; and as the first of these metals is capable of communicating some very noxious qualities to the utensils formed of the second, which are used in the kitchen and in the laboratory; it is of importance to know how to ascertain the proportion of the lead in those vessels, for it is often above what the regulations of government allow. Messrs Bayen and Charlard have given a very good process for determining what quantity of this dangerous metal may be contained in any given quantity of tin. It consists in dissolving two ounces of the tin in five ounces of very pure nitric acid, washing the oxide of tin thus obtained in four pounds of distilled water, and evaporating the water on a *balneum-mariæ*. This evaporation affords nitrate of lead, which must be calcined; and the residue is weighed

heat of a sand-bath, becomes black within like foot, and a vacuum is at the same time formed, and drops of water are produced in the tube. This beautiful phenomenon is explained by considering that hydrogen has a greater affinity than lead with oxygen: a farther proof of which is, that this metal does not act at all upon water. English glass contains a good deal of oxide of lead: Hydrogenous gas, re-acting upon that oxide, gradually abstracts from it the oxygen which it contains, and combines with it to form water, while the lead regains its metallic colour.

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weighed as the quantity of lead contained in the two ounces of tin; allowing some grains for the additional weight which it must have acquired by oxidation, as well as for the other metallic substances, such as zinc and copper, which may possibly be contained in the tin. Those chemists thus ascertained, that fine wrought tin contains about ten pounds of lead in the hundred weight; and that again, that which is sold as common tin, contains generally twenty-five pounds of lead to the hundred weight. This is an enormous proportion of lead, and those who use vessels of common tin are certainly exposed to no small danger. It is almost continually met with in those vessels which are very much in common use; such as measures for distributing fluids, particularly wine. It is easy to see, that a liquor which becomes so quickly sour, must combine with the lead, and convey into the viscera of the poor wretches compelled by necessity to drink it, the seeds of disease, which becomes the more afflictive and fatal because its cause is often unknown. Pewterers have several ways of ascertaining the fineness of tin and the quantity of the lead which it contains. Bare inspection is often sufficient to them; and when this is not sufficient, the weight and the sound of the metal are all that they require farther in order to judge of it. They have two methods of assaying. The one called *the assay by the stone*, is performed by running the melted tin into an hemispheric cavity, cut in a thunder-stone, and terminating in a gutter. The appearances which the tin exhibits as it cools, its colour, the roundness of its surface, the depression of the middle part of its surface, the sound which proceeds from that part of the metal contained in the gutter when twisted backwards and forwards, are so many

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marks which the skilful workman carefully observes, and by which, from long habits of observation, he is enabled to determine exactly the quality of the metal under examination. However this be, the mode of assay employed by the Parisian pewterers, does not appear to be so accurate as that used by the pewterers in the other parts of the kingdom. This second assay is called the assay *by the ball*, or *by the medal*; because it consists in running the tin to be assayed in a mould which gives it the form either of a ball or of a flat mass, in form like a medal. The weight of this moulded specimen is then compared with a piece of fine tin, of equal bulk, run into the same mould. The more the tin examined exceeds in weight the specimen of fine tin, the greater is the quantity of the lead with which it is alloyed. Messrs Bayen and Charlard, with good reason, prefer the latter of these modes of assaying, as its principles are surer and less liable to fallacy, than those circumstances on which the workman determines in the assay of the stone.

Lead is applied to a great many purposes. It enters into many mixtures; pipes for conveying water are formed of it. Its oxides are used in making glass and preparing enamels. It is used to imitate the colour of yellow precious stones, and to render fusible the matters used for glazing earthen ware. Vessels and other utensils for many purposes in ordinary life are made of this metal, but the use of them is not without danger to the health. Water suffered to stand in leaden basins or fountains, is liable to acquire noxious qualities from the lead. The vapour of this metal is dangerous to the workmen who melt it; and its dust still more so to those who file or grate it down. This metal, by insinuating itself into some corners of the stomach, and fixing there, occasions the most painful colics, which are often

often attended with the vomiting of a green bile, and cause the belly to flatten, and contract the navel inwards. It has been observed, that antimonial emetics and purgatives are the happiest medicines in such cases. Navier recommends various alkaline sulphures for poisoning by preparations of lead, as well as against the effects of arsenic and corrosive mercurial muriate. That physician praises alkaline sulphure and sulphureous waters, more especially for their good effects in removing the palsy and tremulous motions, which usually continue to effect patients after the painter's colic. The plain inference from these facts is, that we must cease to employ preparations of lead internally, and make use of it only as an external medicine; and besides, it should not be used even externally but with all the precautions necessary when we employ a violent repulsive.

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C H A P. XVIII.

Of Iron.

IRON, to which the alchemists gave the name of *Mars*, is an imperfect metal, of a livid white colour, inclining to grey, and disposed in small facets. It is susceptible of a very fine polish, and may be made very brilliant. It is so hard and elastic as to be capable of destroying the aggregation of any other metal.

Iron emits a smell, especially when it is rubbed or heated. It has likewise a very strong stiptic taste, which acts powerfully on the animal œconomy.

Iron is, next after tin, the lightest of all metallic substances. A cubic foot of forged iron weighs five hundred and forty-five pounds. It may be hammered into plates; but being very hard, and liable to become much harder under the hammer, it cannot be beat into leaves. Its ductility, when drawn into wire, is much more considerable: it is drawn into very fine threads, which are used as strings to harpsichord keys. This
pro-

property appears to depend on its tenacity. Iron is, in fact, the most tenacious of all metals next after gold. A thread of iron one-tenth of an inch in diameter is sufficient to support, without breaking, the weight of four hundred and fifty pounds.

Pure iron has a peculiar crystalline form. In furnaces in which iron has been slowly cooled, there are found quadrangular pyramids articulated and branched, and consisting of octohædrons inserted one into another. We owe this observation to M. Grignon master of the forges at Bayard in Champagne. Lastly, besides all the properties which iron possesses in common with other metallic substances, this metal exhibits three properties which are entirely peculiar to itself. One of these is magnetism, or the property of being liable to be attracted by the loadstone, and of acquiring the virtues of the loadstone, either when it has remained long in an elevated situation, or in a direction between north and south; or when it has been employed as a conductor to the electric fire of thunder, as is evinced by a variety of facts; or when two pieces of iron are smartly rubbed one upon another. The second of the singular properties of iron is that of taking fire, and melting suddenly when struck with a flint; a phænomenon to which the poets unanimously ascribe the first discovery of fire. The third peculiar property by which it is distinguished, is that of being found with manganese in plants and animals; the humours of animal bodies owe in part their colour to it: it is even probable that those organic beings themselves form the metal; for plants growing in pure water contain iron which may be obtained from their ashes.

Iron is a metal which abounds very much in nature; for, independently of what plants and animals contain,
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it is found in almost all coloured stones, in bitumens, and in most metallic ores. But here we are to treat only of such mineral matters as contain a great deal of iron, and are wrought for the purpose of extracting the metal from them. In those ores, which are very numerous, iron exists either in a metallic state, or in oxide, or mineralized by different substances.

1. Native iron is distinguished by its colour and malleability. It is very rare, and is only found accidentally in iron ores. Margraf found it in a fibrous form at at Eibenstock in Saxony: Dr Pallas has discovered in Siberia a mass amounting to 1600 pounds; and M. Adanson asserts, that it is common in Senegal. Some mineralogists think those specimens of native iron are products of art, and have been on different occasions buried under ground.

2. Iron is very often in the state of rust more or less oxidated. It then forms ochraceous iron ores. All earths coloured brown or red are of this kind.

3. We must beware of confounding with ochres those iron ores which are called *bog ores*. They do, indeed, contain oxidated iron; but that oxide is combined with phosphoric acid, which appears to have been produced by the decomposition of vegetables. Bog irons are distinguished into rich and poor, fusible and dry. The rich is but very little rusted, and contains but a very small proportion of earth. Fusible iron melts very easily, and affords cast iron of a good quality; the metal being in it united only to some stones which easily melt. Dry iron is more calcined, and mixed with some very refractory substances. All bog iron, in general, is usually arranged in layers like stones, and appears evidently to have been deposited by water. It is often in the form of pebbles, or flat irregular spherical bodies. Organic matters, such as wood, leaves,

leaves, barks, shells, are not unfrequently met with in the state of bog iron. This kind of transmutation seems to suggest the idea, that there is analogy between iron and organic bodies. A portion of phosphate of iron, contained in these, which abound more than any other iron ores, communicates to this metal the property of being more brittle when cold. Bergman, who was acquainted with iron in this state, but did not determine its nature, called this phosphate of iron *siderites*; some German chemists have since called it *water iron*. We will afterwards explain how this salt may be separated from iron that is brittle when cold.

4. The eagle stone, or *ætites*, is a variety of bog iron. Eagle stones are bodies of various forms, commonly oval or polygonous, consisting of concentric layers, disposed around a nucleus which is often moveable in the centre of the stone. The drying and contraction of these layers has formed a cavity in the middle, in which some fragments of various sizes float at liberty. This stone has received its name from an opinion that eagles put it into their nests, and that it helps them to lay their eggs more easily, and promote the effects of incubation. It has been hence inferred, that this stone would act powerfully on the foetus in the mother's womb. Some authors go so far as to assert, that the pains of a lying-in woman may be brought sooner on by binding an eagle stone to her thigh, and kept back by binding it to her arm.

5. The *hæmatites* is a kind of muddy iron ore, which appears to be formed in the same manner as stalactites. It derives its name from its colour, which is commonly red like blood, though subject to varieties. The hæmatites usually consists of layers covering one another, and composed of convergent needles. The superficies of this

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ore is covered over with tubercles. Hæmatites are diversified, not only by colour but by form too. There is for instance the needled hæmatitis found in Lorraine; the tuberculated hæmatitis; the hæmatitis in bunches of grapes, or *hæmatitis botrytis*, &c. These ores are pretty often found with muddy iron; and are deposited on a great many different bodies.

6. The *loadstone* is nothing else but an ochraceous iron ore, very hard and very refractory; which, however, some persons think not very remote from the metallic state. It is known by its property of attracting filings of steel. It is found in Auvergne and in Biscay, in Spain. It is distinguished by the diversities of its colour into several varieties.

7. *Emery, smyris*, is a grey or reddish iron ore, considered by a number of mineralogists as a kind of hæmatitis. It is very hard and refractory: great plenty of it is found in the isles of Jersey and Guernsey. It is ground in mills into a powder, and used in that form for polishing glass and metals.

8. *Sparry iron* is an oxide of iron in combination with carbonic acid, and worn by the action of water. It is usually of a white colour; there is, however, of this ore stained with almost every different colour, grey, yellow, red. It is always in plates of various sizes, and semi-transparent like spar. It is of considerable gravity, and is often regularly crystallized: it is found in considerable quarries, often mixed with pyrites, as for instance at Allevard in Dauphiny; sometimes it is mixed with grey silver ore, as the iron of Baigorri; and sometimes with manganese, as that of Styria. Some chemists think it to be a spar in which the metallic oxide has been deposited. Sparry iron is decomposed by itself in close vessels; and it then yields carbonic acid. What remains is iron in a black

powder, which may be easily melted by the action of a strong fire. The manganese which it frequently contains, renders it liable to be altered by the action of air, and makes it take a brown colour, when it loses its form and consistency.

9. Nature likewise presents us with iron in a saline state combined with the sulphuric acid, and forming green sulphate of iron or copperas. This salt is found in the galleries of iron mines, especially in such as contain *pyrites* among the iron ore. It is sometimes found in green crystals, or in the form of beautiful stalactites: on other occasions, again, it is not so pure, but appears to have suffered some alteration. If it has lost only the water of its crystallization, it is of a white or a greyish colour: it is then called *fori*. When somewhat more thoroughly calcined, it is yellow, and is called *missy*. If the calcination has been carried so far as to drive off a considerable part of the acid, the sulphate of iron is then red, and bears the name of natural *colcothar*, or *chalcite*; when mixed with inflammable matters this salt is called *melanteri*, from its black colour. All these matters have received the common name of *atramentarious* stones, as being, no less than sulphate of iron, good materials for making ink.

10. Iron is often found in combination with sulphur; it then forms *martial pyrites*. This ore has received the name of pyrites, because it is hard enough to afford a great abundance of sparks when struck with steel. We call this combination native sulphure of iron. Martial pyrites are commonly in small round masses, which are sometimes regular. They are most generally spherical, cubic, or duodecahedral. Their form is subject to many varieties; a fact which the reader of Henckel's Pyritology cannot fail to be convinced of. Some of them are externally

ternally brown and iron coloured; others yellowish, and even at the surface pretty much like copper ores. They are all yellow and of a copper appearance within; and they consist mostly of needles or pyramids of a number of sides, with their summits converging towards a common centre. Pyrites are usually dispersed near beds of iron ore, and scattered among clays and through coal mines. The uppermost stratum of a coal mine is almost always pyritous. All pyrites are easily decomposed. No strong heat is requisite to drive off the sulphur which they contain. Almost all of them alter of themselves when exposed to the air, especially if the situation be moist: they swell, break, lose their lustre, and are covered over with a greenish white efflorescence, which is nothing else but sulphate of iron. It appears that this alteration, which has been called the *vitriolization of pyrites*, depends on the joint action of air and water on the sulphur. Sulphuric acid is thus formed; which, dissolving the iron, rises above the pyrite in a form resembling vegetation, by separating gradually the small pyramids of which the mineral consists. But all pyrites do not effloresce with the same facility. The globulous pyrites, the colour of which is very pale, and the contexture not very close, effloresce the readiest. Such as are of a bright copper yellow, and consist of small plates very neatly arranged one over another, effloresce not without great difficulty, and should be carefully distinguished from the former, as they differ from them in colour, form, texture, and other properties.

II. Iron is likewise met with in combination with arsenic, and both of them in a metallic state. This ore, which is true *mispickel*, is white, sparkling, granulated, or with facets, and does not, like the arsenical pyrites,

properly so called, contain any sulphur. Wolfram was formerly thought to be arsenical iron ore; but is now known to be tungsten ore.

12. Black iron may be distinguished by its colour, its being liable to be attracted by the loadstone, and being insoluble in acids. This iron is sometimes crystallized in the form of polyhædrons, or round plates: it displays clouds of very bright rainbow colours; such is that of the isle of Elba. It there forms a considerable mountain which is wrought not by running shafts, but by cutting down the mountain. The Swedish iron ore is likewise black but not crystallized: it is in masses more or less solid, and mixed with quartz, spar, asbestos, &c. It is often hard enough to take a polish, and its surface then reflects images like a looking-glass. This, therefore, as well as the last mentioned, has received the name of *ferrum speculare*: it is found in pretty large quarries. This iron is subject to varieties in colour; sometimes it is perfectly black, and the black ore is the most subject to the attraction of the loadstone; sometimes bluish, and the loadstone has then less influence upon it; it is at other times grey, and it then scarce obeys the attraction of the loadstone. The iron of Norway is also black; but it is usually in small scales like mica, and often mixed with garnets and schorls. Black iron is sometimes found in grains: it is also in cubic crystals; which circumstance has caused some naturalists to give it the name of galena of iron, or *eisen-glants*. When micaceous iron ore is black, it is called *eisen-mann*; and it is thought to be more particularly worthy of that name when the scales are very large: when the scales are red, and covered with a dust of the same colour, it is called *eisen-ram*. The iron in black octohædral crystals, very regular, and scattered through a kind of hard schistus or steatites, which we get from Sweden, Corsica, &c. appears

appears to belong to this class of iron ores. It is attracted by the loadstone, and very brittle. The lamellated brilliant iron of Framont is of the same kind.

Although the several kinds of black iron ore, which I have arranged together under this article, appear to have a striking analogy with one another, yet many mineralogists consider them as very different, and arrange them separately. The cause of this diversity of opinions concerning them, is our being as yet but very imperfectly acquainted with their nature. It appears that some among those ores approach nearer to the metallic state; such as the octohædral iron of Corsica and Sweden, which M. Mongez compares to martial *Æthiops*. This species is very subject to the attraction of the loadstone: others, again, are nearer the state of oxide, such as the iron of the isle of Elba, and especially the *eisen-mann* and *eisen-ram*, which refuse to obey the loadstone. All of these ores seem to be nothing but oxides of black iron, owing their formation to water, and in the state of *Æthiops* more or less crystallized.

13. Iron is sometimes found in the form of a blue dust; sometimes of a brighter, and sometimes a deeper colour. In this state it is called *native Prussian blue*. It is mixed with vegetable earths, particularly peat earth.

14. Lastly, as iron is more plenteous than any other metal, it is often found mixed with sand, clay, or chalk; and a great many earths and stones are coloured by it.

Iron ores are assayed in the dry way in the following manner: After being reduced to powder they are mixed with twice their own weight of pounded glass, one part of calcined borax, and a little powdered charcoal; this mixture is well triturated: it is then put into a crucible with a little marine salt added to cover the crucible, and urged with fire till it melt. When the whole

becomes perfectly cool, it is found to contain a small spherical button of iron often crystallized at the surface and more or less malleable.

Bergman proposes the assaying of iron ores in the humid way. He employed the muriatic acid to dissolve iron, and precipitated it by an alkaline prussiate. When there were other metals mixed with the iron, he calcined and separated them by the nitric and the acetic acids; and after that dissolved the iron by the muriatic acid.

The treatment of iron ores is varied according to the state of the metal. Some ores need no preparation before they be melted; others must be pounded and washed, and sometimes even roasted, to render them soft and fusible.

Muddy iron and sparry iron are wrought in the same way; both being melted on coals. The furnaces used in melting iron vary in height from twelve to eighteen feet. Their cavity is in the form of two quadrilateral pyramids, with their bases joined nearly at the middle of the height of the furnace: this cavity is called (in French) *etalage*. A hole, through which the metal may pass when melted, is perforated through the bottom of the furnace; corresponding to this hole, which is stopped with earth, there is a triangular channel cut in the sand to receive the metal. The operation begins with putting into the bottom of the furnace a few pieces of burning wood; coals are laid upon the wood; and upon the wood the ore with some matters to promote its fusion. The matters employed for this purpose are usually calcareous stones, called (in French) *castine*, with some argillaceous stones, under the name of *arbue*, and sometimes quartz or flints. The ore, the stones, and the coal, are alternately put into the furnace, care
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being taken to cover over the whole mass with a layer of coal, which must reach to a equal height with the upper opening of the furnace. Thus disposed, the mass is urged with two large bellows till it melt. When the iron melts, it passes through the coals, and is thus reduced to a metallic state. The stony matters, as they melt and vitrify, contribute to the fusion of the iron, which begins at the narrowest part of the furnace. The melted metal is collected at the bottom of the furnace into a place called the *crucible*; from this it runs thro' the aperture in the bottom of the furnace into the reservoir prepared for it in the sand. It here forms what is called *cast iron*. A vitreous matter called *slag* passes after the iron: it is formed by the vitrification of the gangue of the ore with the earths which were added to facilitate the fusion of the iron. It is of a green whitish blue, or yellow colour, which is communicated to it by a part of the oxide of the melted iron.

The iron thus obtained is brittle, and without ductility. Metallurgists differ in opinion concerning the cause of this property of cast iron: some have thought it to depend on the metal being intermixed with slag. Others have attributed it to the metal not being entirely reduced, but still containing a portion of oxide. Brandt thought it to be arsenic; and M. Sage thinks it is zinc which renders cast iron brittle. Bucquet considered cast iron as iron imperfectly reduced, and still containing an intermixture of oxide. Bergman, after examining this iron with great industry, concluded its fragility to depend on the intermixture of a certain quantity of an extraneous matter, which he thought to be a peculiar metal, and distinguished by the name of *syderites*: that matter has been discovered to be a compound of iron with the phosphoric acid. Syderites, as we shall

hereafter show, is likewise found in certain irons. The true cause of the fragility, fusibility, granulated texture, and other peculiar properties of cast iron, has been determined beyond a doubt by the ingenious researches of Messrs Vandermonde, Monge, and Berthollet. They have shown, that cast iron contains both oxigene and coal: the last of which it has absorbed when in fusion in the high furnace. To the various proportions in which it contains these two extraneous bodies, cast iron owes its peculiar properties, and the varieties by which these are diversified.

Metallurgists distinguish various kinds of cast iron; white, grey, black, &c. They give the name of speckled iron to that which is variegated with blackish spots on a grey ground. White cast iron is the worst kind: it is almost a semi-metal. The grey is between the first mentioned and the black; which last is esteemed the best, as it affords, the most easily, iron of a good quality. These differences depend on the various proportions in which the oxigene, and still more the coal, is intermixed with the iron. When the proportion of the charcoal is considerable, and it is uniformly intermixed, the cast iron is then black: when the proportion of the charcoal is less, the cast iron is grey. An imperfect mixture, too hastily cooled, gives speckled cast iron. White cast iron contains the smallest proportion possible of charcoal. The nature and the use of cast iron, and the process for converting it into iron, are affected by all of these qualities. The above-mentioned philosophers have discovered, that when cast iron is melted again, there is always separated from it a portion of charcoal intimately combined with iron. This compound, which has been hitherto called *plumbago*, forms a crust on the ladles in which the cast iron is taken out to be cooled.

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In order to convert cast-iron into iron, it must be purified from the coal and the oxigene which it contains. A strong fire, which may penetrate through the whole mass, is requisite to effect this reduction. At an high temperature, the charcoal naturally attracts the oxigene, burns, and is disengaged with effervescence, in the form of carbonic acid gas. To accomplish this, the cast iron is taken to a refining furnace. It is a forge furnace, with its hearth somewhat hollow; the cast iron is put into it, and covered over with a good deal of charcoal. The fire is now blown till the cast iron be melted; when brought into this state, it is repeatedly stirred, with the heat still continued. The stirring causes it to expose more surface to the heat; and by this means the charcoal seizes more of the oxigene, in consequence of which it is more completely burnt, and disengaged in carbonic acid gas. The metal appears also to detach from itself at the same time a portion of *syderite*, or phosphate of iron. It is next to be hammered into bars. The hammering, by compressing the particles of the metals, contributes to the separation of the carbure and oxide of iron which it still contains; it consequently effects what could not be effected by the fusion from its being incomplete. The iron is repeatedly beaten and heated till it be brought to the desired form and purity. Forged iron is either soft or brittle. Soft iron is very ductile; and when broken, which cannot be done without bending it, it appears to consist of threads or fibres: this has gained it the name of *nervous iron*. But its nervous appearance is accidental; for even the softest iron, if broken smartly at a single blow, does not appear nervous. The grain of this metal affords a better criterion of its quality. The other species of forged iron is more brittle: it has
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coarse grains, and appears to consist of small scales. This, again, is either brittle when hot, or brittle when cold. The cause of its fragility is now known. That which is so brittle when cold is known to contain much more syderite or phosphate of iron than what is contained in any other sort of iron: still as iron is more ductile, it is found to contain less syderite; and the softest iron contains none at all. To separate this salt from iron, and to determine its quantity, the metal may be dissolved in sulphuric acid, diluted in water; the solution when suffered to settle, by degrees deposits the phosphate of iron in a white precipitate, which may be taken up and weighed.

Iron is artificially converted into steel. For this purpose, shorts bars of iron are inclosed in an earthen box, filled with a cement, which is usually made up of very combustible matters; such as soot from chimnies, or coals of animal matters: sometimes ashes, calcined bones, marine salt, or ammoniac are added; but these matters are often more hurtful than serviceable. The box is now shut, and exposed to heat for ten or twelve hours, till the bars become pretty white, and begin to soften. In this operation the iron is purified, and completely reduced by means of the combustible matters with which it is closely surrounded. Such parts of it as were not perfectly in a metallic state, are now enabled to return to that state; and the phosphate of iron, if any yet remains, appears to be now entirely decomposed. The iron, being thus softened and dilated, absorbs part of the surrounding charcoal; and cemented steel appears therefore to be a preparation of pure iron completely reduced with charcoal. It differs from iron, as containing charcoal; and from cast or crude iron, as not containing, like it, any oxigene together with

with the charcoal. If cast iron be deprived of its oxigene, and yet suffered to retain its charcoal, it will become steel; and again, if you add charcoal to pure iron, without adding to it any oxigene, it will likewise be converted into steel. Steel is much more fusible than iron: and therefore bars of iron, converted by cementation into steel, are softened to such a degree that the carbonic acid, which is disengaged in bubbles, swells the surface of the metal into small cavities, which are sufficiently discernible. The steel which exhibits these appearances is called *ben-steel* *. The differences of steel depend on the iron's having been more or less completely reduced, on the quantity of the charcoal contained in it, and on its being slowly or quickly cooled; tempering compresses its particles more closely upon each other, and renders it very hard, dry, and brittle.

It is plain, that what renders all these preparations necessary is, because this metal is more difficult to melt than any other, adheres much more obstinately to the oxigenous principle, and has a stronger tendency to combine with it.

There are ores, especially black iron ores, such as that of the isle of Elba, in which the metal is so plentiful, and so little altered, that there is no occasion for converting it first into cast iron. It is only softened in a refining furnace, and immediately submitted to the hammer. This is called the *Catalan method*. It cannot be used except with ores which contain but a small portion of extraneous matters that can run into *slag*.

Sparry iron ores afford iron so pure, and so easily reducible, that they melt very readily, and greedily absorb

* *Acier poule*.

absorb charcoal as they are reduced. They are on this account called *ores of steel*.

A very intense heat is requisite to melt iron. Iron filings cast into the midst of a pan with burning coals, or even against the flame of a taper, instantly kindle, and produce very lively sparks; such too are the sparks which issue from a piece of steel when struck against stones. When these sparks are collected upon white paper, they are found to be melted into a kind of drops or scoriæ. This metal, when exposed to the focus of Trudaine's burning-glass, suddenly emits flaming and burning sparks. Macquer, who melted both steel and iron in that lens, observed steel to be the most fusible of the two; which is owing to its being combined with charcoal. When melted iron is slowly cooled, it takes, as we have already observed, a peculiar crystalline form. M. Mongez describes it as a pyramid with three or four sides.

A stream of vital air poured on iron in filings, causes it to burn with as much rapidity as the heat of the focus of the lentile in the garden *de l'Infante*. If into a bottle filled with vital air you immerse a piece of iron wire, twisted into a spiral line, with a small bit of lighted tinder at one end, the metal suddenly takes fire, and burns with a rapidity and a flame which are very remarkable. As in all these instances of fusion the iron becomes brittle, is reduced to oxide, and at the same time takes a black colour, iron-smiths, and all who have any occasion to work the metal, consider it as not being fusible; and with them it is a maxim that iron is absolutely infusible. This opinion, however, proves, when strictly examined, to be erroneous; for when submitted to the action of a very strong fire, without being at the same time exposed to the action of air,

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iron melts almost without alteration. In our accurate experiments we obtain small buttons of soft ductile iron.

Iron, though so very hard and refractory, is very easily calcined or reduced to oxide. As soon as it begins to turn red hot, it combines with oxigene, and burns without any discernible flame. A bar of iron, after being kept red hot for a considerable time, exhibits on its surface scales which may be beaten off with the hammer, (and are called by the French workmen *batitures de fer*.) The metal of these scales is but oxidated in part, for they are still liable to be attracted by the loadstone. A more perfect oxide of iron may be obtained by exposing filings of steel under a muffle; and the scales may by this means be still sooner formed. These are converted into a reddish brown powder, not liable to be attracted by the loadstone, which is called *astringent saffron*. We call it *red oxide of iron*; and the scales we called *black oxide*. The black oxide contains from 20 to 25 parts of oxigene to the hundred; the red oxide contains from 32 to 34 of the same principle. The oxides of iron differ according as they approach nearer to the one or the other of these two degrees. Some are of a yellow brown colour; others chestnut; and others again of the most beautiful red, like carmine. All of these oxides when mixed with earthy matters and exposed to a very strong heat, melt into a blackish porous glass. They are in part reduced when heated slowly in close vessels: However short the time during which they have been exposed to the air, they give out when reduced a certain quantity of carbonic acid; a circumstance which proves that they attract this acid from the atmosphere. This acid may be also produced from the charcoal which the iron contains,

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and which becomes acid by absorbing the oxygen disengaged from them as they are reduced.

Red oxide of iron is very easily reduced with the help of combustible matters. On being mixed with a little oil and heated slightly in a crucible, they become black, and very subject to the attraction of the loadstone: But in this operation they lose not all the oxygen which they contain; they only pass into the state of black oxide.

The purest iron soon loses its metallic lustre when exposed to humid air: it is then covered over with a pulverulent brown yellow crust. This matter is called *rust*. Common iron is much more liable to rust than steel. The more the particles of the metal are attenuated and divided, the more rapid is the alteration which it suffers from air. On this principle is prepared the medicine known in pharmacy under the name of *aperient saffron of Mars*. To produce it, iron filings are exposed to the air and watered; and by this means they come to rust very speedily. It is formed still more quickly of iron in the state of *Æthiops*, or black oxide, treated in the same manner. In this alteration the metal is agglutinated into masses, which are levigated before being employed in medicine. The formation of the rust of iron was thought to be owing to the action of the air; but it is now known to be water which calcines the metal in this manner. Some experiments peculiar to myself lead me to consider *aperient saffron of Mars* as a combination of oxide of iron with carbonic acid. I have distilled *this saffron of Mars* in a pneumatocchemical apparatus, and obtained from it a large proportion of this acid. The iron was then changed into a black powder, very subject to the attraction of the loadstone. M. Joffe, apothecary at Paris, has communicated

ted to the Royal Society of Medicine a similar process for obtaining speedily *martial Æthiops*. He advises the making the *aperient saffron of Mars* red hot in a retort with a balloon perforated with a small hole, fitted, but not luted, to it. By this means the heat disengages the carbonic acid, which M. Joffe suffers to escape thro' the hole perforated in the balloon; and the iron then remains in the state of black oxide in powder or *martial Æthiops*. I have by this means often crystallized caustic potash and soda, rubbed over the sides of the balloon fitted to the retort, In consequence of the carbonic acid from the iron uniting with the alkali, that neutral salt is formed to which we have given the name of carbonate of potash or soda. I have made many other experiments, and have given an account of them in a particular Memoir, (*Chem. Mem. & Observ.* 1784). From all of them I am convinced that this matter is a true neutral salt formed by oxide of iron with the carbonic acid. Rust should therefore be called *carbonate of iron*, to distinguish it from the genuine oxides of this metal. This salt is precisely the same with what Bergman calls *aerated iron*. This theory, too, has been adopted by Macquer. It explains very naturally how iron comes to contract rust so speedily in humid and impure air; how it comes to be altered so quickly and so entirely in places where the air is corrupted by the respiration of animals, by combustion, or by vapours proceeding from animal matters; as, for instance, in stables, stalls, and houses of office, &c. Iron is of all metals the most liable to alteration from the contact of air, and the alteration is not confined to its surface. Very thick bars of iron are often rusted half way through.

Water acts powerfully on iron when cold. It divides it,

it, and even dissolves a part of it, according to the experiments of M. Monnet. The purer the iron is, and the more air it contains, so much the more of it does water dissolve. When iron is for some time stirred about in water, it appears to be divided into very minute parts; and on decanting the water, which is a little turbid, it deposits a very fine black powder, which has received the name of *Lemery's martial Æthiops*. This powder must be carefully dried by a moderate heat, and in a close vessel, such as an alembic, lest the contact of the air should rust it. This martial Æthiops is very subject to the attraction of the loadstone; it is a black oxide of iron formed by water. As this operation is very tedious and delicate, various chemists have attempted to simplify it. Rouelle, in making up this preparation, made use of the *mouffoirs de la Garaye*, and by that means obtained a very fine Æthiops in much less time than what is consumed in Lemery's process. I believe M. Joffe's method, which is much more expeditious, might be advantageously substituted in its place. We will hereafter give some other processes for preparing *martial Æthiops*. Lemery's is effected by an actual decomposition of water; the hydrogenous gas is disengaged, and the iron is oxidated by absorbing twenty-five parts of oxigene to a hundred. We will very soon treat more at length of this decomposition of iron by water.

We have already mentioned, that when steel in bars is heated to a certain degree, and suddenly immersed into cold water, it becomes very hard and very brittle. The hotter the steel, and the colder the liquor into which it is immersed, so much the more eminent do these qualities become. This operation is called *tempering*. Steel may at pleasure be caused to assume any

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degree of hardness. We can also deprive it of its *temper*, by heating it to the same temperature at which it was tempered, and suffering it to cool slowly. This effect of water on steel appears to depend on the sudden cooling producing a change on the disposition of its parts, and injuring its crystallization. All metals admit of being hardened by tempering; but the more infusible the metal, so much the more eminent the degree in which it acquires this quality. Iron therefore is more susceptible of it than any other.

About two years since a much stronger re-action was discovered to take place between water and iron. M. Lavoisier putting iron and water together into a bell-glass above mercury, observed that the iron rusted, and the water decreased in quantity in proportion as an elastic fluid which filled the upper part of the apparatus was disengaged. The fluid disengaged proved to be *inflammable gas*. The iron had gained an additional weight, and was oxidated. M. Lavoisier conjectured that the water might contain oxigene, and that the inflammable gas, the other principle of the water, might be disengaged, in consequence of the oxigene uniting with the iron. He afterwards made a more decisive experiment, in conjunction with M. Meusnier: in that experiment, water in vapour introduced into a gun-barrel made red hot, afforded a large proportion of *inflammable gas*: The inner part of the gun was found to have acquired additional bulk, and was become black, brittle, and lamellated, much like the iron ore of the isle of Elba. The metal was found to have gained an increase of weight; and the additional weight which it had acquired, taken together with the weight of the *inflammable gas*, corresponded precisely to that of the water decomposed. The portion of iron

oxidated by this means was found separate from that which had not undergone the same alteration. It formed an interior cylinder, thicker than the exterior part; and differing greatly from it in texture, colour, consistency, and form. In order to succeed in this experiment, it is requisite to make the iron fully red hot; for heat contributes greatly to the separation of the principles of the water. And when the gun-barrel is not thoroughly red hot, and the water not in an highly elastic state when it passes through it, no *inflammable* gas is disengaged, nor is the water decomposed. This has happened with various philosophers; who not making the iron hot enough, and introducing the water into it in a liquid state, have not obtained the same results as M. Lavoisier, and have of consequence denied water to be decomposable, though Synthesis concurs to justify M. Lavoisier's inferences from analysis, as has been incontrovertibly shown by the same gentleman and M. Mongez. There are many other occasions on which water is, in like manner, separated into its constituent principles, and gives rise to many very important phenomena, of which we will hereafter have occasion to take notice. Such is the experiment by which water was discovered to be a compound consisting of 0,14 of hydrogene with 0,86 of oxigene.

Iron does not combine in its metallic state with earthy or stony matters; but oxide of iron facilitates the fusion of all kinds of glass, communicating to it a green or brown colour. The colours which oxide of iron communicates to other bodies are various, according as it is more or less completely oxidated. This oxide possesses likewise the property of assuming and communicating more or less consistency to those stones with
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which it is naturally or artificially mixed, and of making them liable to dilution in water.

Neither barytes, magnesia, nor lime, acts observably upon iron.

The pure fixed alkalis and ammoniac, when dissolved in water act in a sensible manner on this metal: In the course of a few days digestion on it, the liquors become foul, and give a precipitate of a small portion of *Æthiops* or black oxide of iron: And, as has been observed by the chemists of the Academy of Dijon, a certain quantity of hydrogenous gas is disengaged during the reaction of these substances; a circumstance which proves that the water contributes to it, as the hydrogenous gas can be given out only in consequence of its decomposition; to which no doubt the alkalis contribute.

Iron may be dissolved in any of the acids. M. Monnet has observed, that the concentrated sulphuric acid cannot act on this metal, unless it be boiling. On distilling this mixture to dryness, there are found in the retort sublimated flowers of sulphur, and sulphate of iron in a white mass, which may be dissolved in one part of water, but being decomposed by the heat, affords no crystals. The sulphuric acid diluted in two parts of water readily dissolves iron filings cold; at the same time when the metal is dissolved, a considerable quantity of hydrogenous gas is disengaged. By putting a lighted taper to the mouth of the matrafs, after keeping it stopped for some time with the hand, it may be made to detonize with a considerable noise. This gas burns with a reddish flame, sometimes emitting very small sparks, like those of iron filings. Macquer, Bergman, and Mr Kirwan, think that in this instance of combination the sulphuric acid disengages a

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great part of the phlogiston of the iron, and that the *inflammable* gas belongs solely to this metal. This opinion appears to have been built on the belief that *inflammable* gas might be extracted from iron alone, without any intermedium, merely by the action of fire. But it is at present a well established fact, that the hydrogenous gas disengaged from iron by heat is always in strict proportion to the water which it contains; and it is no less certain that the water added to the sulphuric acid gives out, in consequence of being decomposed, hydrogenous gas. 1. Because the concentrated sulphuric acid affords only sulphureous gas. 2. Because in this state it cannot act upon iron without the aid of heat, and even then acts upon it but very faintly. 3. Because, whenever water is added, the reaction becomes more rapid, and hydrogenous gas is produced. 4. Lastly, because the concentrated sulphuric acid is in part decomposed by the iron when there is no water added; whereas when water is added to the solution, the acid remains without diminution, and only combines with the oxide of iron. The proof of this last fact is, that the same quantity of alkali is required to saturate this acid after it has acted on iron as before. In this operation, therefore, it is the water which oxidates the iron, as was long since conjectured by M. de la Place; and has been fully proved by Messrs Lavoisier and Meusnier.

While the sulphuric acid diluted in water acts upon iron, a portion of the metal is precipitated in a black powder, which was taken by Stahl for sulphur, and has been found by M. Monnet to be *martial Æthiops*. That black oxide appears to be more than sufficient for the saturation of the acid. As soon as one part of the iron is combined with one of the acid, although the

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the acid be not nearly saturated, yet the solution ceases, and it no longer acts upon the metal. M. Monnet, who first made this observation, remarks, that when water is poured into the mixture, the acid begins again to act upon the metal. The cause of this phenomenon is, that the water which was united with the sulphuric acid has been absorbed by the sulphate of iron which is already formed, while the acid which remains unsaturated cannot act upon the iron, till by the addition of a new quantity of water more of the metal be reduced to oxide. The sulphuric acid dissolves more than half its own weight of iron. That solution, after being filtered and evaporated, affords by cooling a transparent salt, of a beautiful green colour, in rhombic crystals. This is the *martial vitriol*, or *green copperas* of commerce. We call it sulphate of iron.

People do not take the trouble of making up this salt artificially, because nature supplies it in abundance, and it is easily extracted from *martial pyrites*. All that is requisite is, to leave those sulphures exposed for some time to the air. The moisture of the atmosphere contributes to their decomposition; they become covered with a white efflorescence, which needs to be dissolved in water and crystallized before it can afford sulphate of iron. This decomposition of pyrites depends, according to Stahl, on a double affinity. Sulphur is with him a compound of *phlogiston* and *vitriolic acid*. Neither water or iron, when taken each by itself, can decompose sulphur: But when these two substances are made to act upon it together, the iron detaches and attracts to itself the phlogiston of the sulphur, and the *vitriolic acid* combines with the water to dissolve the metal. Such of the pyrites as are less disposed to effloresce, among which are the brilliant pyrites, effloresce readily after being deprived by roasting of a part of the sulphur

phur which they naturally contain. The *vitriol* is separated from it by washing. The solution of this salt deposites at first a certain quantity of iron in the state of ochre. The liquor is not evaporated and crytallized till after this depositum be precipitated. The modern opinion concerning the efflorescence of pyrites is, that the sulphur, which in them is divided as in its combinations with alkaline substances, combines with a portion of oxigene to form sulphuric acid, which being diluted by the water of the atmosphere, enters into union with the iron, not without exciting heat, and dissolves it. What adds a very considerable weight to this opinion is, that the contact of air is necessary to the efflorescence of pyrites, and that moisture which contributes greatly to their *vitriolization*, acts in this instance in the same manner as in the solution of iron. Such is the origin of the hydrogenous gas, which is disengaged in this operation when performed *in vacuo*.

Sulphate of iron has a green emerald colour, and a very astringent taste. It sometimes reddens syrup of violets; but it does not uniformly produce this effect. From the experiments of Kunckel and M. Monnet, it appears that these crystals contain a quantity of water equal to more than half the weight of the salt. If this salt be suddenly exposed to a pretty strong heat, it becomes liquid, like any of the other salts which are more soluble in heat than in cold; when dried, its colour is a whitish grey. If it be heated at a more intense fire, it gives out so much of its acid in the form of sulphureous gas, and becomes red; in this state it is called *colcothar*. Sulphate of iron, when calcined till it becomes red, attracts the moisture of the atmosphere in a very sensible manner by means of the sulphuric acid which it contains. When distilled in a retort, and in a reverberating furnace, this salt affords at first a wa-

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ter which is faintly acid, and is called *dew of vitriol*. The balloon must be changed when we wish to obtain the concentrated sulphuric acid separately; which, when the heat is very intense, appears black as it passes into the receiver, and exhales a suffocating smell of volatile sulphureous acid. What enables it to display these phænomena is, according to the pneumatic theory, its having lost a part of its oxigene, which has become fixed in the iron. Towards the end of the operation, the acid distilled assumes a concrete crystalline form, and it is now called *glacial sulphuric acid*. This experiment, which is described by Hellot, did not succeed with M. Baumé; but among chemists in general it is considered as certain and infallible. The glacial sulphuric acid, when distilled in a small retort, gives out sulphureous gas, and becomes white and fluid. It owes its concrete state to the presence of this gas. It combines with water with hissing and heat, and on this occasion too, gives out sulphureous gas. Such is Northausen's fuming *oil of vitriol*, and the concrete salt obtained from it by a moderate heat, of which I have given an analysis in a Memoir published among the Memoirs of the Academy for the year 1785.

The residue remaining after the distillation of sulphate of iron is red, and resembles colcothar. When washed with water, there is separated from it a white salt but little known, and called *colcothar salt*, or *fixed salt of vitriol*. What remains is a red insipid earth, which is pure oxide of iron, and is called *mild earth of vitriol*.

Sulphate of iron, when exposed to the air, becomes a little yellow, and is gradually covered with rust, by absorbing oxigene from the atmosphere. By this absorption of oxigene, it is by degrees more and more calcined, till it become incapable of remaining united with the sulphuric acid. A solution of this salt exhi-

bits the same phenomenon when brought into contact with the atmosphere; and either the one or the other may be used as an eudiometer.

Cold water dissolves a quantity of this salt equal to half its own weight: hot water dissolves still more of it; but when sufficiently impregnated, it appears to be rendered turbid by a quantity of ochre more or less considerable. This ochre is separated from it by filtration; and the solution, when cooled, gives pale green transparent rhomboidal crystals. The supernatant liquor affords by evaporation a new parcel of crystals: and after it is deprived of all that it can afford by crystallization, there remains a blackish brown, or a brown yellow mother water, not susceptible of crystallization. When evaporated by a strong heat, and suffered to cool, this mother water forms a soft unctuous mass, which powerfully attracts the moisture of the atmosphere. When this mass is thoroughly dry, it affords a greenish yellow powder. According to M. Monnet, the mother water of sulphate of iron contains iron in the state of a perfect oxide. He made himself certain of this fact, by forming directly, with the help of heat, a solution of genuine oxide of iron in this acid. The solution is brown, and not susceptible of crystallization.

The oxide of iron may be separated from the mother water, not only by aluminous earth, but also by copper and iron filings, to which perfect sulphate of iron is not liable.—A strongly saturated solution of this perfect salt, if exposed to the air, changes in a certain space of time into a mother water of the same nature with the two last-mentioned, by attracting oxigene from the atmosphere.

Sulphate of iron is decomposable by lime and alkalis. Lime-water poured into a solution of this salt produces

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a precipitate in flakes of a deep olive green colour; a portion of the precipitate is again dissolved in the water, and communicates to it a reddish tinge. In the years 1777 and 1778 I presented to the Academy two memoirs on precipitates of iron obtained by caustic alkalis, or by alkalis not caustic, in which I have accurately described the phænomena which attend those precipitations, and the state of the iron in these different circumstances: I shall here give the chief facts which they afford in relation to sulphate of iron. Caustic fixed alkali precipitates the sulphuric solution of iron in dark green flakes, which are again dissolved in the alkali, forming a kind of martial tincture of a very beautiful red colour. When a smaller portion of the alkali is put into the solution, the precipitate may be taken up and converted into blackish *Æthiops*, or black oxide of iron, by drying it rapidly and in close vessels. If these two precautions were neglected, the iron would very soon become oxide, on account of its being moist and divided. Potash, saturated with carbonic acid, or carbonate of potash, forms a greenish white precipitate which does not dissolve again in the alkali. This difference is owing to the carbonic acid, which unites with the iron as fast as it is separated from the alkali by the sulphuric acid. The precipitate formed by concrete ammoniac, or ammoniacal carbonate, is of a greenish grey colour: a part of it is again dissolved in the salt, and communicates to it a red tinge: so that the phænomena which ammoniac produces in this solution are in one respect directly opposite to those of the fixed alkalis; caustic fixed alkali dissolves the precipitated iron very readily; carbonated potash not without the greatest difficulty.

Astringent vegetable matters, such as nut-galls, sumac, husks of nuts and pomegranates, quinquina, cypress

prefs nuts, logwood, tea, &c. cause sulphate of iron to yield a black precipitate. That precipitate, which cannot be mistaken for iron, is so much attenuated as to remain suspended in the liquor. On adding to this mixture a little gum arabic, the iron precipitate is permanently suspended, and the composition forms the black liquor known under the name of ink. We do not yet certainly know what passes on this occasion. Macquer, M. Monnet, and many other chemists, think the precipitate of ink to be combined with some principle of the nut-gall which disengages it from the acid. They appear with some reason to think that principle in an oily state. M. Guanetti, a physician at Turin, has made a number of experiments on iron precipitated by astringents from its solutions. The result of his researches, which he has given in his analysis of the waters of St Vincent, proves that this precipitate is not liable to be attracted by the loadstone; that it becomes so, however, when heated in a very close vessel; that it is soluble in acids without effervescence; and that the solution no longer receives a black tincture from nut galls: from which facts it may be inferred, that the iron is combined with the astringent principle, and that they exist together somewhat in the state of a neutral salt. In the third volume of the Elements of Chemistry by the Academy of Dijon, there is a series of experiments on the astringent vegetable principle, which seem to represent that substance as of a similar nature with acids. According to those chemists it reddens vegetable blue colours; combines with alkalis; decomposes sulphures; dissolves, and appears to neutralize metals; decomposes all solutions of metals with peculiar phænomena; ascends in distillation without losing its power of acting on metals, and displays a vast number of other properties which we have not here room to enlarge upon.

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The experiments and inductions of the academicians of Dijon have since been confirmed by the researches of Scheele. That celebrated chemist has discovered, that the simple infusion of nut-galls in water separates from it a peculiar acid, susceptible of crystallization, which detaches iron from any other acids, and communicates to it a black colour, by bringing it nearer to a metallic state. We call this salt the *acid of galls*, or the *gallic acid*. Its history will occur in the vegetable kingdom.

A phenomenon still more difficult to understand than the action of nut-gall on sulphate of iron, is the decomposition of this salt by an alkali calcined with bullock's blood. By this means we obtain a precipitate of a beautiful blue colour, and insoluble in acids. This precipitate is called *Berlin*, or *Prussian blue*, because it was first discovered in the city of Berlin. Stahl relates, that a chemist, of the name of Diesbach, happening to borrow from Dippel a quantity of fixed alkali to precipitate a solution of cochineal, Dippel gave him alkali on which he had distilled animal oil. The salt caused Diesbach's solution to yield a blue precipitate. Dippel inquired into the cause, and prepared by a simple process the Prussian blue, which was made known to the world in the year 1710, in the Miscellanies of the Academy of Berlin; but the mode of preparation was not communicated. Chemists laboured eagerly to discover the process for preparing it, and at length succeeded. In the year 1724 Woodward published in the Philosophical Transactions a process for preparing this colouring substance.

To make Prussian blue, mix four ounces of nitre fixed by tartar with as much dried bullock's blood. Calcine this mixture in a crucible till it be reduced to a coal and cease to emit flame, Wash it with as much
water

water as may be requisite to dissolve the whole of the saline matter, which is called *phlogisticated alkali*, or *colouring lixivium*; and let this lixivium be concentrated by evaporation. Next dissolve two ounces of sulphate of iron and four ounces of aluminous sulphate in a pint of water. Mix this solution with the alkaline lixivium; a greenish depositum is produced, which must be separated by the filter and muriatic acid poured upon it. The depositum then takes a darker and more beautiful blue colour; and is to be dried by a moderate heat, or in the air.

Many chemists have since attempted both to prepare and to form a theory of Prussian blue. As to its preparation, it is at present known that many other substances render alkali capable of producing a blue precipitate of iron.

Geoffroy, in the Memoirs of the Academy for the year 1725, says, that he found all coals of animal matters capable of communicating this property to alkalis. M. Baumé asserts, that *phlogisticated alkali* may be prepared with the coals of vegetable substances by a stronger heat. Spielman has made it with bitumens; Brandt with foot. The manufactories of Prussian blue are very numerous; and in each of them, it would appear different methods are employed in the preparations. M. Baunach informs us, that in Germany the hooves, horns, and hides of cattle are used for this purpose. All animal matters, however, do not appear equally proper for the Prussian lixivium. I have attempted ineffectually to prepare it with the bile in the same manner as with the blood of bullocks. What I obtained was an alkali which produced in a solution of vitriol a greenish white precipitate; and the precipitate was entirely dissolved in the muriatic acid.

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Prussian blue. Brown and Geoffroy thought it to be the *phlogistic* part of iron extricated by the lixivium of the blood, and united with the aluminous earth. Abbé Menon thought it to be alkali. Macquer, in a memoir which has deservedly been considered as a master-piece by every chemist, and is inserted among the Memoirs of the Academy for the year 1752, has refuted the opinions of those chemists. He thinks Prussian blue to be nothing but iron combined with an excess of the inflammable principle which it receives from the *phlogisticated* alkali, and the alkali from the bullock's blood. He observes, 1. That Prussian blue, when exposed to heat, loses its colour and becomes simply iron again. 2. That this blue is insoluble even by the strongest acids: 3. That alkalis are capable of dissolving the colouring matter of Prussian blue and absorbing it till it be saturated. For this it is sufficient to heat an alkaline lixivium upon Prussian blue till the alkali become unfit to discolour it. Alkali, when thus saturated with the colouring matter of Prussian blue, is found to have lost most of its properties. It is no longer caustic; it does not effervesce with acids; it does not decompose barytic salts; it precipitates all metallic salts; and this precipitation appears to take place by virtue of a double affinity, the affinity of the acid with the alkali, and the affinity of the metallic oxide with the colouring part of that salt. Alkali is thus capable of destroying the colour of a twentieth part of its weight of Prussian blue; and is then saturated with colouring matter. The acids disengage from it a small quantity of blue sediment; and the sulphate of iron is then instantly precipitated in perfect Prussian blue.

In regard to alkali prepared in the common way, Macquer observes, that it is far from being completely saturated with colouring matter; and that, from this

circumstance, it produces at first a green precipitate from the solution of sulphate of iron. In fact, the portion of the alkali which is saturated does give a blue precipitate; but the portion which is not saturated precipitates iron in the state of ochre, which gives a green tinge to the blue precipitate by intermixing the blue with yellow. According to this ingenious theory, the acid poured on the precipitate serves to dissolve that portion of it which is not in the state of Prussian blue, and to improve the colour of that which is. The alum, which is added to the solution of sulphate of iron, saturates the alkali which is not already saturated with colouring matter; and the earth of this last added salt, being precipitated with the Prussian blue, brightens its dye. As it is necessary to pour acid on the precipitate of sulphate of iron, in order to brighten Prussian blue, that acid may be added to the alkali before it be employed to precipitate the iron; for while the acid saturates the pure part of the alkali, it does not combine with that which is impregnated with colouring matter, and is capable of instantaneously forming fine Prussian blue. This *phlogisticated* alkali may be also saturated with bullock's blood, by digesting it over Prussian blue till it cease to discolour it. Macquer has recommended this alkali saturated with acid as a good test for determining the presence of iron in mineral waters: but M. Baumé has observed, that this liquor itself contains a certain quantity of Prussian blue, by which it may occasion mistakes when applied to this purpose. He proposes, therefore, to digest it for some time with a little vinegar by a moderate heat, in order that it may deposit the blue matter which it contains. Such were the results of Macquer's ingenious experiments on Prussian blue; but that celebrated chemist was himself very sensible

sible of what was wanting, more especially to explain the nature of the colouring substance. He could not be persuaded to consider that substance as pure phlogiston; for he could not conceive how, as is pretended in this hypothesis, iron supersaturated with the phlogistic principle could all at once lose both the property of obeying the attraction of the loadstone, and that of being soluble in acids, which, according to Stahl, this metal owes to its containing phlogiston. M. de Morveau, in his excellent dissertation on phlogiston, has made the first attempt to determine the nature of the colouring part of Prussian blue. He obtained, by distilling two drachms of this compound, twenty-two grains of a yellow empyreumatic liquor, which effervesced with alkaline carbonates, and communicated an high red colour to blue paper, but has not been once mentioned by Geoffroy or Macquer, though they likewise distilled Prussian blue.

M. Sage, in the year 1772, sent to the Electoral Academy of Mayence a memoir on *phlogisticated alkali*, in which he calls it animal salt. The lixivium of fixed alkali, treated with blood and saturated by digestion on Prussian blue, as directed by Macquer, is, according to M. Sage, a neutral salt formed by the animal acid with fixed alkali. It affords, by insensible evaporation, cubic crystals, either octohædral or in prisms with four faces, terminating in pyramids having the same number of sides. This salt decrepitates on coals: by a violent heat it melts into a semi-transparent mass soluble in water, and proper for making Prussian blue. M. Sage thinks that it is the phosphoric acid which neutralizes the alkali in this neutral salt; because when the mixture of alkali with bullock's blood is made very hot, it melts, and exhales an acrid vapour attended with white brilliant sparks, which in his opinion are nothing

thing but phosphorus in flame. This opinion concerning the nature of the acid of the Prussian alkali would be established as a certain truth, if on the one hand it afforded phosphorous when distilled with coal, a phenomenon which in that case Prussian blue might likewise exhibit; and if, on the other hand, Prussian blue could be formed by combining phosphate of potash or soda with a solution of iron. But, as M. Sage has given no experiments to this purpose in his memoir, his theory cannot be admitted:

The chemists of the academy of Dijon have in their Elements adopted a part of this last doctrine: They consider the *phlogisticated* lixivium as a neutral salt. They recommend crystallizing it by evaporation in preference to purifying it by vinegar, as has been proposed by M. Baumé. This salt, according to them, is very pure; when cast on nitre in fusion, it causes it to detonize. They say nothing of its decomposition, or the nature of its principles; they call it crystallized Prussian alkali.

Bucquet, on precipitating with muriatic acid, and afterwards filtrating a lixivium prepared for Prussian blue, observed, that the alkali, tho' apparently pure after this operation, and without any appearance of Prussian blue, yet deposited a blue powder. After filtrating it above twenty times in the space of two years, in order to separate the blue precipitated after each filtration, he at length found the liquor to be no longer capable of forming Prussian blue with the solution of sulphate of iron. I have kept by me for more than eight years a small portion of this lixivium; during the two last of these years it has given no precipitate, but has deposited a light bluish coating on the sides of the phial, and has maintained the same colour. I have had occasion to observe

observe this phænomenon twice since I heard Bucquet mention it in his lectures ; and I believe it to be invariable. The Duke de Chaulnes showed Macquer a colouring lixivium, which, on being previously mixed with an acid, became incapable of affording Prussian blue. That chemist thinks, that the lixivium which exhibited this phænomenon must have been prepared in metal vessels. Bucquet concluded from the facts which he is above mentioned to have observed, 1. That the Prussian blue is entirely contained in the alkali employed to precipitate the sulphate of iron : 2. That acids alone are sufficient to separate the alkali : 3. That when this alkali has, in the course of a certain time, deposited all the colouring matter which it contained, it is no longer fit for affording Prussian blue.

The *Journal de Physique* for the month of April 1778, contains observations on Prussian blue by M. Baunach apothecary at Metz, which contribute greatly to support Bucquet's opinion. After describing the process of the German manufactories for preparing Prussian blue, M. Baunach affirms, that the lixivium prepared in those manufactories by the fusion of alkali, and the hoofs, horns, and hides of cattle, causes all metals, and even calcareous earth, to yield a blue precipitate. This alkali, after precipitating metals, dissolves them ; and they may be separated by the muriatic acid, when they will display a very beautiful blue colour. The singular facts related in that memoir, such as the distillation of the Prussian blue produced by this lixivium, which affords neither oil nor ammoniac ; the solubility of the blue precipitate formed when muriatic acid is poured on this lixivium in nitric acid ; the circumstance of calcareous earth being found in the nitric acid which has destroyed the blue ; and the existence of a peculiar

phlogisticated earth in it which he could not dissolve: these facts taken together seem to suggest, that this blue is not of the same nature with that which is precipitated from the common phlogisticated lixivium which Macquer found to contain, and which can be produced only from blood.

Since these experiments on Prussian blue, Scheele has made a new series of researches on the nature of this composition, which, together with some observations of which I have not yet spoken, throw much new light on its nature.

1. Common Prussian blue, distilled by naked fire, affords a very large quantity of hydrogenous gas, together with oil, ammoniacal carbonate, and a little acid phlegm. This gas burns with a blue colour like that which rises from marshes; its smell is empyreumatic; lime-water communicates to it the property of burning with a red flame and detonizing in the air, for it absorbs from the lime-water a part of its carbonic acid. M. de Laffone has considered the gas of Prussian blue as a peculiar inflammable gas. Prussian blue, after this analysis, is in the form of a blackish powder, subject to the attraction of the loadstone. M. de Morveau has observed, that it becomes orange before taking this colour. He is even of opinion, that Prussian blue converted by heat to orange might be advantageously employed in painting.

2. Ammoniac heated above Prussian blue decomposes it by seizing on the colouring matter, and leaving the iron in the state of brown oxide. Macquer made this fact known in the year 1752. Meyer, following him, has given the name of *tinging liquor* to this volatile alkali saturated with blue colouring matter, and recommends the use of it in analysing mineral waters.

I have observed, that when caustic ammoniac is distilled on Prussian blue, the liquor which passes does not give a blue colour to solutions of iron; from which it follows, that the colouring matter is not so volatile as ammoniac. When only a part of this salt is extracted by distillation, the residue is of an olive green colour: on diluting it in distilled water and filtrating the liquor, it is found to have impregnated the water with colouring matter; and it accordingly affords a very lively Prussian blue with sulphate of iron.

3. In the year 1780 I discovered, that when lime-water is digested on Prussian blue, it dissolves the colouring matter, if assisted with a little heat. The combination is very rapid: the lime-water acquires a colour, and the Prussian blue takes the appearance of rust. Filtrated lime-water is of a fine bright yellow colour: It does not turn syrup of violets green; it has not an alkaline taste, and is not precipitated by the carbonic acid; it does not combine with other acids: in a word, it is neutralized by the Prussian colouring matter; and when poured on a solution of sulphate of iron, it affords a deep blue, which needs to be brightened by an acid. Scheele has mentioned this Prussian lime-water, without knowing any thing of my experiments; notwithstanding of my having given an account of the result in my Elements of Chemistry, printed in the year 1781. He is of the same opinion with me, that this combination is the very best that has been proposed for determining the presence of iron; because it contains either none, or at least very little, Prussian blue completely formed.

5. The caustic fixed alkalis instantaneously destroy the colour of Prussian blue with cold. I have observed that a pretty lively heat is produced on this occasion;

that the alkalis, when pure, discolour much more Prussian blue than when saturated with carbonic acid; and that they afford much more blue with solutions of iron when pure than when carbonated.

6. I found magnesia likewise to possess the property of discolouring Prussian blue, but not in so eminent a degree as lime.

7. Prussian blue in powder, if cast on nitre in fusion, produces some sparks; from which we may infer, that it contains a combustible matter.

8. Prussian blue, prepared without alum, becomes very subject to the attraction of the loadstone on being slightly calcined; but common Prussian blue never acquires this property by the action of fire.

9. Prussian blue discoloured by alkaline matters, and in the state of oxide of iron, regains a part of its blue colour if an acid be poured into it. The cause of this phenomenon seems to be, that all the colouring matter has not been carried off by the first action of the alkalis; and a portion is still retained among the particles of the oxide of iron.

All these facts show, that the colouring part of Prussian blue acts as a peculiar acid which saturates alkalis, thereby forming neutral salts. This is the opinion of a great many chemists, particularly of Scheele; whose researches on this matter I am now to give some account of. That celebrated chemist has shown by his experiments, 1. That the lixivium of blood, or phlogisticated alkali, is decomposed by the carbonic acid of the atmosphere; and that all other acids separate from it the colouring part. 2. That this colouring part is fixed, and retained in the lixivium by a small quantity of pure iron, or sulphate of iron. 3. That when it is disengaged by acids, by means of distillation, it fills the balloons with a vapour
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which makes solutions of iron to yield a blue precipitate, 4. That when Prussian blue, or the lixivium of blood, is distilled entirely, it affords, together with the colouring matter, other products which alter that matter, such as sulphur; and that therefore the colouring matter cannot be obtained pure by this process. 5. That Prussian alkalis, distilled with sulphuric acid, precipitate a good deal of Prussian blue, and afford a liquor impregnated with the colouring matter: the blue precipitated in this operation depends on the iron dissolved in these triple salts or compounds of alkali, colouring matter, and iron. 6. That oxide of mercury, or red precipitate, carries off the colouring matter of Prussian blue by ebullition, in a quantity of water equal to twice the weight of the two substances; and that by distilling this mercurial Prussian lixivium with iron and sulphuric acid, the iron reduces the mercury after the acid has disengaged the colouring part: the colouring matter being dissolved in the water of the receiver as fast as it is disengaged, retains a portion of sulphuric acid: to separate it Scheele mixes a little chalk with the colour, and distills it by a moderate fire; the colouring matter then passes very pure into the receiver: and as it is disengaged in the state of an elastic fluid, according to what has been observed by M. Monge, it may be received and dissolved in water with the tubes and the apparatus which we have already repeatedly described.

After these experiments on the affinities of the Prussian colouring matter, its obstinate adhesion to alkalis, and the means for obtaining it perfectly pure, Scheele in a second memoir examines into the nature of this substance and its combinations with alkalis and metallic oxides. Although his experiments are numerous and very accurate, Scheele does not prove in this memoir that the Prussian colouring matter is a peculiar

acid. On the contrary, he endeavours to show, that it contains inflammable gas, ammoniac, and a carbonaceous principle. He acknowledges, however, that it renders a solution of soap turbid, and precipitates *berzels* or alkaline sulphures; and in a letter to M. Crell, he calls it the colouring acid. We give this substance the name of the *Prussic acid*, and call its saline combinations *Prussiates* of potash, soda, ammoniac, &c. In a note by the translator of Scheele, this acid is said to be decomposable by the acid of nitre; and a process of M. Westrumb's is likewise given for obtaining Prussiate of potash very pure. It consists in saturating caustic potash with colouring matter, digesting it over white lead to purify it from any hepatic gas which it may contain, mixing it with distilled vinegar, exposing it to the sun, as directed by M. Scopoli and Father Bercia, in order to precipitate the iron entirely, and adding to it two parts of rectified alcohol. The Prussiate of potash is then deposited in bright lamellated flakes, washed with a new quantity of spirit of wine, dried, and dissolved in distilled water. Dr Crell says, that Scheele sent him, three months after M. Westrumb, an analagous process for obtaining a test liquor, the purity of which might be depended upon, to ascertain the presence of iron on any occasion.

The Prussic acid, or the colouring matter of Prussian blue, has likewise engaged M. Berthollet's attention, who has made still later experiments upon it than any of the above mentioned chemists. Though that able philosopher is not yet fully satisfied with his researches on this matter; they contain, however, a good many new facts and experiments of such consequence, as to render it proper for us to give here an extract from his memoir, which he has obligingly communicated.

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M. Berthollet first observes, that there are two kinds of Prussiate of iron; the one common Prussian blue, the other Prussian blue that has lost a part of the acid which it possesses in its ordinary state. The last of these he calls *Prussiate of iron with excess of oxide*. Prussian blue is in this state, after being discoloured by an alkali. To separate this excess of oxide, he employs the muriatic acid, which dissolves it, leaving the Prussiate of iron in a neutral state. He observes, with M. Landriani, that when alkali is digested hot on Prussian blue, the alkaline Prussiate then formed dissolves more oxide of iron than if the digestion had been performed with cold. Both of these chemists are of opinion, that an acid added to this triple combination combines with the excess of oxide of iron, and produces a precipitate of Prussian blue, just as when Prussiate of potash is mixed with a solution of iron. They say also, that heat causes this combination to yield a yellow Prussiate of iron, that is, with excess of oxide of iron. According to them the acid added seizes the excess of oxide of iron, and the Prussian blue becoming then less soluble in the alkaline Prussiate, is of consequence precipitated. When the Prussiate of potash, prepared by a moderate heat, has deposited the Prussiate of iron with excess of oxide of iron, by ebullition, it may then be evaporated to dryness, dissolved again in water and mixed with acids; but will not, by any of these expedients, be brought to deposit Prussian blue. M. Berthollet says, that by evaporating the solution of Prussiate of potash thus purified, octahædral crystals are obtained with two pyramids truncated, so as to represent square plates with their edges cut sloping.

This chemist, on mixing a solution of these crystals with sulphuric acid, and exposing the mixture in a

phial to the rays of the sun, observed, that in a short time a blue colouring matter began to appear, and was gradually precipitated till the mixture was entirely decomposed. A mixture of the same kind, preserved in a dark place, does not become blue, nor yield a precipitate, even tho' suffered to stand untouched for a number of months. A strong heat produces absolutely the same effect. From these experiments, M. Berthollet shows, how inaccurate the principles on which the processes recommended for purifying alkaline Prussiates were founded. For, says he, instead of purifying them of a portion of Prussian blue, which chemists pretended to be only accidentally mixed in them, they decomposed most part of the matter which they attempted to purify. As Prussiate of potash is a triple salt, the Prussic acid has but a very faint disposition to adhere with potash, and may be separated from it by any other acid. When the extraneous acid combines with the potash, one part of the Prussic acid combines with the oxide of iron to form Prussian blue, and the other is either volatilized in the state of acid, or reduced to its principles.

The iron precipitated by alkaline Prussiates retains, according to M. Berthollet, no small portion of those salts; by repeated washing it may be purified of them: these lixiviums contain alkalis combined with a small portion of Prussic acid; and the Prussiates with excess of alkali are not separated till after the excess of acid contained in the solution of iron is carried off by the first washings; for the latter washings precipitate the iron in the state of blue from its solutions, which the first do not.

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that the latter crystallizes differently from the former. Mineral acids disengage the Prussic acid, which is in part fixed in the Prussian blue that is precipitated. This led Scheele to think of another combination, from which he might, with greater facility, obtain this acid pure, on which M. Berthollet has made some observations. This process, as we have already mentioned, consists in boiling red oxide of mercury with Prussian blue and distilled water. The Prussic acid then forsakes the oxide of iron to unite with the oxide of mercury, with which it has a stronger affinity, and forms a soluble salt which crystallizes in tetrahædral prisms, terminating in quadrangular pyramids, the sides of which correspond to those of the prisms. To this lixivium, after filtrating it, iron and concentrated sulphuric acid are to be added; the iron unites with the oxygen of the mercury, and afterwards combines with the sulphuric acid; the mercury is precipitated in a metallic state, as appears from its lustre. Scheele next distilled this mixture by a moderate heat, to avoid volatilizing the Prussic acid; but he observed that, however moderate the heat which he employed, the Prussic was always mixed with a little sulphuric acid. To prevent this, he added to the mixture a certain quantity of chalk to fix the sulphuric acid. Concerning this addition, M. Berthollet has observed, that, as Scheele has not specified the quantity, this operation might very easily miscarry, if the chalk were ever so little above what is sufficient to saturate the sulphuric acid: for calcareous Prussiate must then be formed, which, by the law of double affinities, would decompose the sulphate of iron.

M. Berthollet has observed, that the sulphuric acid disengages but a small portion of acid from Prussiate of
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mercury ; and that it combines with the greatest part of that salt without decomposing it, thus forming a triple salt which crystallizes in small needles. According to his experiments, the muriatic acid disengages more of the acid of Prussiate of mercury than the sulphuric acid does ; forming like it a triple salt crystallizable in needles, and much more soluble than corrosive mercurial muriate. Alkalis and lime cause this triple salt to yield a white precipitate. M. Berthollet proves, that alkaline Prussiates do not precipitate barytes from its solutions, as Bergman thought, but join with the solution to form triple salts : he shows that they precipitate aluminous earth. The precipitate which they form with this substance suffers no alteration from the sulphuric acid ; but when digested with sulphate of iron, it forms Prussian blue.

The Prussic acid decomposes the oxygenated muriatic acid, and by absorbing its oxigene, becomes odorate. In this state it does not seem to have any great tendency to unite with alkaline substances ; for they scarce render its smell any thing weaker. It no longer causes solutions of iron to yield a blue, but a green, precipitate. The contact of the rays of the sun renders it blue again ; iron and sulphureous acid produce the same effect upon it. The phenomena appear when oxygenated muriatic acid, sulphate of iron, and Prussiate of potash, are mixed together. M. Berthollet concludes from this, that Prussian blue is liable to no alteration either from light or from the sulphureous acid, and that it owes its green colour, solubility in acids, &c. to its having absorbed oxigene.

If the Prussic acid be supersaturated with oxygenated muriatic acid, and after that exposed to the rays of light, it assumes new characteristic properties. It no longer

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longer combines either with oxide of iron, or with water; but is found precipitated to the bottom of either of these liquors, in the form of oil, with an aromatic smell. If more oxigene be added to it when in this state, and it be now left exposed to the sun, it crystallizes in small white needles. This acid thus oxygenated is reduced to vapours by a moderate heat; these vapours are neither soluble in water nor combustible. M. Berthollet has not yet been able to determine what passes in this operation. Is the Prussic acid simply united with oxigene, without suffering any alteration? or is there one of its principles burnt? I am rather inclined to agree with him in adopting the last of these ideas: For though oxigene appears very little disposed to combine with the Prussic acid; yet the Prussic acid can no longer be restored to its original state, after being treated in this manner with the oxygenated muriatic acid.

The Prussic acid prepared for forming a green precipitate with iron, by means of the oxygenated muriatic acid, forms ammoniac whenever lime or an alkali is mixed with it. Though an acid be poured into this last mixture, yet it does not regain the peculiar odour of the Prussic acid; from which M. Berthollet concludes it to have been destroyed by the mixture of the alkaline or calcareous substance. Although the potash employed were perfectly pure, yet an acid poured in after it, produces an effervescence, and disengages carbonic acid.

From all these experiments, M. Berthollet concludes, that azote, hydrogen, and the pure coaly principle, combined in proportions, and condensed to a degree still unknown, form what is called the *Prussic acid*. The knowledge of this composition enables us to understand

derstand how the Prussic acid comes to be formed in animal matters, in certain vegetable substances, and in ammoniacal muriate contaminated with charcoal. It explains likewise the reason why this acid is so combustible and detonizes with such force with various nitrates, why it affords ammoniacal carbonate by distillation, and why the same salt is formed in it on the addition of oxygenated muriatic acid. M. Berthollet doubts if this singular combination contain oxigene. At least, says he, if the Prussic acid *do* contain oxigene, it contains so very little that the carbonaceous matter is not entirely reduced by it to carbonic acid; for Prussian blue affords, by distillation, a good deal of carbonated hydrogenous gas.

Such are the facts discovered by M. Berthollet. By ascertaining the nature of the colouring matter of Prussian blue, he has proved it not to be a genuine acid, however it may act as an acid in all its combinations. M. Vestrumb and M. Hassenfratz have found in Prussian blue a little phosphoric acid. But the last of these gentlemen shows that acid not to be essential to its nature.

Sulphate of iron very easily decomposes nitre. The decomposition is partly owing to the sulphuric acid, which by combining with the alkali of the nitre, expels the nitric acid; but it is likewise owing in a great measure to the reaction of the iron on the last mentioned acid. If the sulphate of iron employed to decompose nitre be scarcely dry, a large quantity of nitrous acid is then obtained, very red and fuming: the residue, on being lixiviated, affords sulphate of potash, fixed alkali, and red oxide of iron remaining on the filters. But if the sulphate of iron have been well calcined, and the nitre melted, the product obtained will then be very scanty.

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This product consists of two liquors; one of which being of a dark colour, almost black indeed, swims on the surface of the other, which is red and ponderous, like oil above water. Accordingly, M. Baumé considers this liquor as a kind of oil. There afterwards passes into the neck of the retort a white saline mass, which attracts the moisture of the atmosphere, and is speedily dissolved in water with heat, exhaling at the time a strong smell of spirit of nitre, and very thick red vapours. This solution, when saturated with potash, affords sulphate of potash. The white mass is therefore nothing but sulphuric acid rendered concrete by a portion of nitrous gas.

There appears to be no difference between the heavy liquor in the balloon and spirit of nitre obtained in Glauber's way. But the light liquor that swims above, on being mixed with sulphuric acid, produces a lively effervescence; and even a dangerous explosion. Almost the whole of the nitrous acid is dissipated, and the sulphuric acid takes a concrete crystalline form. Bucquet, who communicated this discovery to the Academy, had at first observed, that this concrete acid, obtained by distillation, exhales red nitrous vapours when dissolved in water. He inferred, that the solidity of the acid must be owing to its containing nitrous gas. But to determine this with greater certainty, he attempted to mix the blackish brown nitrous acid, which swims above the red, with sulphuric acid highly concentrated. But at the very instant of the mixture, so rapid a motion took place, that the spirit of nitre poured on the sulphuric acid was expelled with noise to a great distance; and the person who made the mixture was covered all over with sulphuric acid; and there immediately appeared on his countenance a great many red inflamed

inflamed pimples, which suppurated like the small-pox. The sulphuric acid became soon after concrete precisely like that obtained by distillation, of which we have given the history. From this fact it appears that this acid may be rendered concrete as well by nitrous as by sulphureous gas.

The residue remaining after the distillation of nitre by sulphate of iron calcined to redness, is nothing but scoriæ of iron, from which but very little sulphate of potash can be extracted by washing.

The solution of sulphate of iron suffers no alteration from hydrogenous gas. But though the base of this elastic fluid appears to have less affinity than iron with oxigene, as has been shown in the history of the decomposition of water; yet M. Monnet has observed, that hepatic gas communicates to sulphuric mother water the property of affording crystals: And Dr Priestley has reduced brown oxides of iron by the contact of hydrogenous gas. These facts do not contradict our doctrine; they rather confirm it. In fact, iron may be deprived of whatever oxigene it contains above the proportion of 0,28 by the action of hydrogen; but this proportion it obstinately retains, however attacked by that principle. Such is the reason why in these instances of reduction nothing is ever obtained but a black oxide, or martial *Æthiops*, and why iron oxidated by water is always black.

Alkaline sulphures precipitate sulphate of iron with a blackish colour. This precipitate is a kind of martial pyrites, or sulphure of iron.

The nitric acid is rapidly decomposed by iron, which disengages from it a good deal of nitrous gas, especially if the acid employed be concentrated, and the iron in a state of division. The metal is speedily calcined by
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the oxigene which it attracts from the acid of nitre; the solution is of a brown red colour; at the end of a certain time it is found to have deposited oxide of iron, especially if it have been exposed to the contact of air. On immersing into it a new quantity of iron, the acid, as has been observed by Stahl, is dissolved, and the oxide of iron which it held in solution instantaneously precipitated. Yet by employing weak nitric acid and iron in small pieces, a more permanent solution may be obtained, in which the metal adheres with more obstinacy to the acid. This last combination is greenish, and sometimes of a bright yellow colour. Both these solutions, when evaporated, become turbid, and deposit a brown red martial ochre. But if the latter be highly concentrated, instead of affording crystals, it takes the consistency of a reddish jelly, in part soluble in water, the greatest part, however, being precipitated on such an occasion. On continuing to heat nitrate of iron, it gives out a good deal of red vapours; and the magma, becoming dry, affords a brick-coloured oxide. This magma, when distilled in a retort, affords a small quantity of fuming nitrous acid, a good deal of nitrous acid, a good deal of nitrous gas, and some azotic gas. There can be no vital air obtained from it, because the iron retains all the oxigene of the acid. The oxide which remains after the distillation of nitrate of iron is of a lively red colour, and would make a fine colouring matter for painters, &c. The nitrous solution of iron, however highly saturated, has never, on any occasion, appeared to me liable to be precipitated by distilled water. The alkalis decompose it with phenomena diversified according to their different natures. Caustic potash makes it yield a bright brown precipitate: the mixture assumes very speedily a blackish brown colour,

much deeper than that of the former solution. The cause of this phænomena is, that a portion, though a very small one indeed, of the precipitate is dissolved by the alkali. Carbonate of potash separates from it a yellowish oxide, which very soon takes a beautiful orange red colour. If this mixture be stirred in proportion as the effervescence takes place, the precipitate is again dissolved in much greater abundance than that which is produced by caustic potash. M. Monnet has accurately observed this phænomenon, and he ascribes it with good reason to the gas which is disengaged. This solution of iron by fixed alkali bears the name of *Stahl's alkaline martial tincture*. Its colour is a very beautiful red. M. Baumé advises to prepare it with a nitrous solution of iron containing but a small portion of the metal. Stahl again recommended an highly saturated solution. M. Monnet has observed, that a yellow solution affords a copious precipitate, which is scarce dissolved again in alkali, and does not colour it like martial tincture; whereas a very red solution instantaneously forms a martial tincture with the same alkali. Stahl's martial tincture loses its colour in a certain time, and deposits the oxide of iron which it contains. It may be decomposed with the help of an acid. The acid of nitre separates from it a red brick-coloured oxide, which is soluble in acids, and is called *Stahl's aperient saffron of Mars*. Either pure or caustic ammoniac causes the nitric solution of iron to yield an almost blackish deep green precipitate. Ammoniacal carbonate dissolves again the iron which it separates from the acid, and takes a red colour still more lively than that of Stahl's tincture. This solution of iron by ammoniacal carbonate might be of great use in cases in which

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I have never been able to obtain more than a very small quantity of genuine Prussian blue from the red, saturated, nitric solution of iron, by alkali saturated with the colouring matter of that composition. I could never obtain any thing but a blackish precipitate, liable to be again dissolved by the muriatic acid: the liquor, on this last event, assumed a green colour.

M. Maret, secretary to the Academy of Dijon, has sent to the Royal Society of Medicine a process for making *martial Æthiops* very quickly. It consists in precipitating the nitric solution of iron by caustic ammoniac, and in washing and drying the precipitate without loss of time. M. d'Arcet, who was employed by the Society to examine M. Maret's process, did not uniformly obtain the same result. In my Memoirs on Precipitates of Iron, I have determined in what cases M. Maret's process must succeed, and when it is likely to fail. To obtain this *Æthiops*, it is requisite, 1. That the solution of iron have been lately formed, and that very slowly, of weak nitric acid, and iron somewhat divided, both cold. 2. That the ammoniac be recently prepared, very caustic, and, above all, have lost by standing undisturbed for some time the small portion of calcareous earth and blackish combustible matters with which it usually carries up from the sal ammoniac and lime, not extracted in Woulfe's apparatus. 3. That the precipitate be instantly separated from the liquor, and speedily dried in close vessels. Even when all these precautions are carefully taken, the precipitate is sometimes not very black, but rather of a light brown colour. It rises in scales, the under sur-

face of which is blackish ; a circumstance which proves that the contact of air slightly rusts its upper surface. I have obtained a more beautiful and permanent *Æthiops* by precipitating muriatic and acetous solutions of iron with fixed alkali and caustic ammoniac ; washing these precipitates sufficiently, and then drying them speedily in close vessels. Yet I am of opinion, that these *Æthiops*, however pure they may be supposed to be, still retain a small portion of their precipitants and first solvents ; as has been observed by M. Bayen of the precipitates of mercury ; and they cannot therefore be employed in medicine with so much certainty as those which I have above-mentioned. M. d'Arcet, in his report to the Royal Society of Medicine concerning M. Maret's process, has communicated a process of M. Crohare's for making *martial Æthiops*. This apothecary, who is known by a number of judicious chemical operations, prepares *martial Æthiops*, by boiling water acidulated with a little nitric acid, upon iron filings. The metal is immediately slightly oxidated, and affords a good deal of black oxide, or *martial Æthiops*. But in my opinion, M. Joffe's process is preferable to all of these ; it is easily performed, and is attended with no danger.

As iron is often used in procuring nitrous gas, it cannot be improper to observe here, that the nature of this gas is never precisely the same on two occasions ; it varies amazingly, according as the circumstances of the solution are diversified, as the acid contains more or less azote and oxigene, as the iron is more or less disposed to absorb oxigene, as the temperature of the matters is hotter or colder, &c. Gas prepared by this process generally contains more or less azote ; for as iron absorbs a greater proportion of oxigene than most other

other bodies according as it is state ; the essential are there experiments dies that sep shows how gas are to be therefore m purity of air The mur rapidly. A engaged from must be ow same manne phuric acid. action of iron to be differ from the fu was then th riatic acid. tion of water ter, and not still unknow gaged from remains un tion of this cessary to fore. This duces a cor till the acid cipitated in other soluti inclining to

other bodies, and absorbs different quantities of it according as it is more or less completely in a metallic state; the effects of nitrous gas disengaged by this metal are therefore more or less uncertain in eudiometric experiments. This truth, which is applicable to all bodies that separate nitrous gas from the acid of nitre, shows how little the assays of eudiometers with nitrous gas are to be depended upon. Alkaline sulphures are therefore much preferable as tests for determining the purity of air.

The muriatic acid diluted in water dissolves iron rapidly. A large quantity of hydrogenous gas is disengaged from this solution, the production of which must be owing to the decomposition of water, in the same manner as when the metal is dissolved in the sulphuric acid. The hydrogenous gas produced by the action of iron on the muriatic acid was formerly thought to be different in nature from that which is disengaged from the sulphuric solution of iron. This elastic fluid was then thought to be one of the principles of the muriatic acid. But since the discovery of the decomposition of water by iron, it has been proved, that the water, and not the muriatic acid, the nature of which is still unknown, gives rise to the hydrogenous gas disengaged from the muriatic solution of iron; for the acid remains undiminished and unaltered after the exhalation of this gas, and the same quantity of alkali is necessary to saturate it which it would have required before. This solution of iron by the muriatic acid produces a considerable heat; which continues to be felt till the acid be saturated: a portion of the iron is precipitated in real *Æthiops*, in this as well as in all its other solutions. When filtrated, it is of a green colour, inclining to yellow: It is much more permanent than

either of the two former: when inclosed in a phial properly stopped, it deposits no oxide. I have kept by me some of it for eight years; in all which time it has deposited nothing but a very light pale yellow dust. But, again, when it is left exposed to the air, it deposits in a few weeks almost all the air that it contains; and the more it has been brought into contact with air, the brighter is the colour of the precipitate. It is at present known as a certain fact, that this precipitation, which is in the same manner produced in all the other solutions of iron, is owing to the metal absorbing the oxigene of the atmosphere; as I conjectured and suggested to the public in the year 1777. (See my *Memoirs on Chemistry*.)

Stahl announced to the world, that in the combination of iron with the muriatic acid, the muriatic acquired the characteristic properties of the nitric acid. But this fact has not been observed by any other chemist. It appears that Stahl attended only to the yellow-colour of this solution, and the smell which it diffuses: a smell in fact but little different from that of spirit of salt, and much the same with that of the oxygenated muriatic acid.

The solution of iron by the muriatic acid does not crystallize regularly when evaporated. M. Monnet has observed, that if left to cool, when its consistency is that of a syrup, it forms a kind of magma, in which flat needled crystals are observed, which are liable to deliquesce. This magma melts by a very moderate heat; when a stronger heat is applied, it is decomposed, but not so easily as nitrate of iron; and when dry, it takes the colour of rust. There is disengaged from it a portion of muriatic acid, which may be obtained by distillation;

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distillation; and which, as has been remarked by Brandt, carries off with it a little oxide of iron.

The Duke d'Ayen, in four excellent Memoirs on the combinations of iron with acids, which he has given the Academy, has entered into a minute examination of what passes when muriate of iron is decomposed in a retort. He obtained from this operation three very singular products: He first obtained, by a moderate heat, a phlegm slightly acidulated: the muriatic acid was then concentrated; and its gas, though much more volatile than water, was in part fixed by the iron. By a much stronger heat, a part of the acid was volatilized with a little iron, and some crystals, not disposed to deliquesce, were formed in the balloon. At the same time, there were sublimed to the upper part of the retort a number of very transparent crystals, resembling razor-blades, which decomposed the light like the most beautiful prisms, displaying very beautiful shades of red, yellow, green, and blue. There remained at the bottom of the retort a stiptic, deliquiating salt, of a brilliant colour and a foliated form, precisely like that species of talc in large plates, which is improperly called *Muscovy glass*. This last salt, when exposed to a violent heat in a stone retort, was decomposed, and afforded a sublimated product of a still more surprising nature than any of the former products. It was an opaque matter, truly metallic in its nature, and when examined by the microscope, it exhibited regular crystals, or sections of hexagonal prisms, which the Duke d'Ayen compares to the square pieces of wood used in flooring rooms. Those crystals were as brilliant as the best polished steel, and equally subject to the attraction of the loadstone; this was iron partly reduced

and sublimated *. Art seems, in this instance, to effect an imitation of nature, which sublimes black oxides of iron by the fire of volcanoes, in the form of bright polished plates like steel. Such at least appears to be the origin of the specular iron of Mont d'Or and of Volvic; which, according to the accurate observations of M. de l'Arbre, physician at Riom, is always in the chinks of lavas.

From these particulars, it appears what singular phenomena the science of chemistry offers to our observation, and what valuable discoveries it promises to such as shall pursue a train of experiments with the accuracy and perseverance of the Duke d'Ayen. Let it not escape us, that this reduction of iron favours the doctrine of gases, and that similar products might be obtained by the same process from many other solutions of metals.

The muriatic solution of iron is decomposed by lime and alkalis, like all martial solutions; but these precipitates are not so much altered, and may be very easily reduced, especially such as are produced by caustic alkalis. I have already observed, that this combination affords by precipitation the purest *Æthiops*, or black oxide of iron, that can possibly be obtained. Alkaline sulphures, sulphurated hydrogenous gas, and astringents, decompose this solution

* I have in my cabinet a black iron ore, with small and very brilliant laminæ, half a line in breadth, the form of which nearly resembles that of the crystals obtained by the Duke d'Ayen. They are very thin small scales, of a very sparkling grey iron-colour, disposed slopewise, so as to intersect each other in all directions, and dispersed in a reddish opaque quartz, or a kind of coarse jasper. This beautiful specimen comes from Lorraine. The iron of Framont is of the same nature. A.

solution as well as the other two: lastly, Prussian alkalis, or alkaline Prussiates, cause it to yield a very beautiful blue precipitate.

Water impregnated with carbonic acid easily dissolves iron: all that is necessary in order to accomplish this combination is to put iron filings into the acidulated liquid, and to leave the mixture to digest during a few hours. This liquor, after being filtrated, has a pungent and somewhat styptic taste. Messrs Lane and Rouelle have observed the carbonic acid to possess this property. Bergman calls this combination *aerated iron*, and says, that when exposed to the open air it acquires a rainbow-coloured pellicle; that it is decomposable by pure alkalis; but that alkalis saturated with carbonic acid produce not the same effect upon it. This solution gives a green tinge to syrup of violets, and affords with calcareous Prussiate a very brilliant Prussian blue. When exposed to the air or heated, it precipitates brown oxide of iron. The name which we give to this combination is *carbonate of iron*. Iron has a strong tendency to combine with the carbonic acid. In nature we often find it in this state. Muddy iron ores and sparry iron appear to consist mostly of this combination. Ferruginous mineral waters often contain iron in the state of carbonate of iron. This salt, when separated from the water, and dried, is scarce soluble in that fluid. But it dissolves plentifully in liquid carbonic acid, subsiding, however, in a precipitate when the acid is volatilized. We know not in what manner the fluoric and the boracic acids act upon iron.

This metal very readily decomposes sulphuric salts, particularly sulphate of potash or soda. I have treated those salts with iron in a crucible, and have found them reduced by such treatment to the state of sulphures.

phures. The lixivium of a sulphure of this kind is of a very deep green colour. A few drops of acid very speedily destroy the colour of this metallic tincture. The greatest part of the iron, oxidated by the oxigene of the sulphuric acid, remains undissolved in the water of the lixivium; and acids disengage from it a large quantity of sulphurated hydrogenous gas.

Iron causes nitre to detonize. On throwing into a red hot crucible a mixture consisting of equal parts of iron filings and dry nitre, in a certain time a very rapid motion is excited, and a great many bright sparks fly out of the crucible. When the detonation is over, the crucible contains a reddish oxide of iron, of which a small part is combined with the alkali; when this matter is washed, the water dissolves the alkali, and the oxide of iron remains on the filter. This oxide was formerly called *Zwelfer's saffron of Mars*. It is of a reddish yellow colour, and is scarce soluble in acids. The alkali separated from it by washing is caustic, according to most chemists; for it is generally thought that metallic oxides act like pure lime on this salt, thus saturated with carbonic acid *.

Iron easily decomposes ammoniacal muriate. Two drachms of iron-filings, triturated with a drachm of this salt, give out no ammoniac gas. Bucquet, who distilled this mixture in a pneumato-chemical apparatus with mercury, obtained from it fifty-four cubic inches of aeriform fluid; one half of which was ammoniac gas, and the other half hydrogenous gas. Four ounces of the same

* It is to be observed, that since Black's theory, concerning the causticity of lime and alkalis, has been received, the proper experiments have not yet been made to determine whether metallic oxides and lims, properly so called, agree in their phenomena in this respect. And, till experiment determine, we can say nothing certain on this head. A.

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same filings, with two ounces of ammoniacal muriate, afford, when distilled in a retort with a common receiver, about two drachms of liquid ammoniac, impregnated with a little iron, which it soon deposits in the state of oxide of iron. The residue of these operations is muriate of iron. What occasions the decomposition of ammoniacal muriate by iron is, that the metal eagerly combines with muriatic acid: a proof of which is the disengagement of hydrogenous gas, observed to take place during the operation. In pharmacy, there is a medicine prepared of ammoniacal muriate and iron, which is called *martial flowers of sal ammoniac*, or *ens martis*. A pound of ammoniacal muriate in powder is mixed with an ounce of iron-filings: this mixture is exposed in an earthen pot covered with another vessel of the same kind to a fire sufficient to make the under part of the apparatus red hot. In five or six hours there is a yellow matter sublimated, which is to be preserved in a phial: this matter is the *martial flowers*. This substance consists chiefly of sublimated ammoniacal muriate with a little oxide of iron. As the metal very readily decomposes this salt, only a very small quantity of it must be employed, in order that the greatest part of the salt may be sublimed in its natural state. That portion of the oxide of iron which is volatilized, communicates a colour to the ammoniacal muriate, which is at the same time sublimated.

Oxide of iron decomposes this salt better than the metal itself; for it disengages the ammoniac with cold. That which is obtained by distillation is very fluid and sufficiently caustic. I have obtained ammoniac, which gave a slight effervescence with acids, by distilling ammoniacal muriate with half its weight of *aperitive saffron of Mars*, or oxide of iron prepared with access of air,

air, and of consequence containing carbonic acid. In this instance, the carbonic acid disengaged from the iron combined with the ammoniac, and so rendered it effervescent.

Iron is altered in its colour by hydrogenous gas; but the alteration which it suffers has not been yet sufficiently examined. Black oxide of iron is not decomposed by this gas; but the brown or the red oxide easily are, and they then pass into the state of black oxide; for hydrogen robs them of all the oxigene they contain, more than what is requisite to maintain them in the state of black oxide. Sulphur combines rapidly with iron. A mixture, consisting of iron-filings and sulphur in powder, and moistened with a little water, becomes hot in a few hours. It then swells, acquires consistency, absorbs the water, bursts with a discernible crackling, and exhales a good deal of aqueous vapour, accompanied with a foetid odour, very like that of sulphurated hydrogenous gas. When the mixture is a large mass, it takes fire in the space of four and twenty or thirty hours, and as soon as ever the aqueous vapours cease to arise from it. When substances have nearly ceased to act on each other, the heat rapidly increases, and inflammation takes place. The smell then becomes much stronger; it seems to be owing to the hydrogenous gas produced by the action of the sulphur and iron on the water. This smell is mixed with another, that of alkaline sulphures and pure hydrogenous gas: the inflammation observed in this experiment is, no doubt, owing to a copious disengagement of hydrogenous gas; for the flame is more lively than that of sulphur. It rises a foot high, according to M. Baumé's account, who observed this phænomenon on a mixture consisting of an hundred pounds of iron-filings and as much

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much sulphur in powder: it lasts only for two or three minutes; the mixture continued red and burning for forty. M. Baumé explains this inflammation into the disengagement of the phlogiston of the sulphur into the state of fire at liberty. Lemery, the father, has given the name of artificial volcano to this experiment. He imagined the fires which kindle in the interior parts of our globe, and by forcing their way to the surface produce earthquakes and volcanoes, to arise from a similar combustion of pyrites piled on each other, and moistened by water. In his opinion, these awful phænomena might be imitated, by burying in the earth a mixture of sulphur in powder and iron-filings reduced to a paste with water, and covering it over with earth pressed closely down upon it. This experiment did not succeed with Bucquet, who repeated it with the greatest exactness. Dr Priestley seemed to show the reason why it failed. That philosopher observed, that the moistened mixture of sulphur and iron absorbed a certain quantity of air, which might be thought necessary to its inflammation. But, notwithstanding this, the inflammation takes place without the contact of air. It appears, in fact, that the iron being very much divided, reacts on the fluid, and seizes its oxigene; in consequence of which it is calcined, and gives out hydrogenous gas, which takes an elastic form by means of the heat separated from the water. This gas also dissolves a portion of the sulphur, and thus becomes sulphurated hydrogenous gas.

There is a strong analogy between this combination of iron and sulphur by the humid way and the efflorescence of *pyrites*; which, when they are moistened by water, produces sulphurated hydrogenous gas.

Sulphur combines very easily with iron by fusion; the result is a sulphure of iron, or pyrites, arranged in needles.

needles. As in this case the sulphur increases greatly the fusibility of iron, the metal may be instantaneously melted with the help of this combustible body. In order to this, a small bar of iron heated to whiteness, may be applied to a roll of sulphur, and the melted matter which runs from them received into water. It will be found in the fluid in brittle blackish globules, resembling *pyrites*, and, like them, in the form of small slender concentric pyramids.

Iron with arsenic affords a brittle mixture, which is but very little known.

This semi-metal appears to exist in many iron ores; and it is in consequence of being intermixed with it that iron is brittle when hot.

With cobalt, iron forms a semi-metal, with small close grains, hard, and not easily broken.

It does not appear capable of combining with bismuth.

In combination with antimony, it forms a brittle alloy with small facets, which yields but very little to the hammer. Iron has more affinity than antimony with sulphur; and is of consequence capable of decomposing sulphure of antimony. To effect this decomposition, make five ounces of the points of horse-shoe nails red hot in a crucible; throw upon them a pound of pulverized sulphure of antimony; and apply speedily to this mixture a heat sufficiently strong to melt it: when it is pretty well melted, add an ounce of nitre in powder, to promote by a thorough fusion the separation of the scoriæ from the semi-metal; let the mixture be now left to cool, and the antimony will be found by itself not impregnated with any iron. If the mixture employed consist of one part of iron with two of sulphure of antimony, the semi-metal will be alloyed with iron. The scoriæ which are found above antimony alloyed with iron, and

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and prepared with nitre and tartar, are of a yellowish colour like amber, which they owe to the iron contained in them. Stahl has, on this account, called them *succinated scoriæ*. He directs to reduce them to powder; then boil the powder in water, which mixes intimately with the most subtle part of it; decant off the liquor; filtrate it; and detonize the powder remaining on the filter three times with nitre; then wash and dry it: and the matter thus prepared is Stahl's *aperitive saffron of antimoniated Mars*.

It is still uncertain whether zinc be capable of entering into union with iron. Malouin, in his *Memoir on Zinc* (*Academy*, 1742), has shown, that this semi-metal may be applied like tin to the surface of a piece of iron, so as to secure it from the contact of air; a circumstance which shows, that these two metallic matters are capable of entering into combination with one another.

It appears that nickel enters into a very intimate union with iron; for, as Bergman has shown, these two metallic substances can never be entirely separated.

Mercury can contract no union with iron in its metallic state. Ineffectual attempts have been made to produce a direct combination of these two substances; but their oxides have been combined. Navier has observed, that a snowy white precipitate may be obtained by mixing together a solution of iron and a solution of mercury, both made by the sulphuric acid; and on evaporating this mixture, small flat crystals are formed in it, very thin, and resembling the boracic acid. Navier is convinced that these crystals are a combination of iron with mercury.

Lead cannot enter into union with iron.

It appears that iron and tin may be combined by fusion.

tion. That art which consists in coating the surface of iron with tin, or preparing white iron, shows this combination to be possible. The surface of iron to be tinned must be smooth and sparkling. For this end, it is sometimes cleared with an acid, sometimes filed, and sometimes coated with sal ammoniac: when prepared in this manner, it is immersed vertically into a vessel full of melted tin; its position in the vessel is repeatedly changed, in order to bring it more completely in contact with the tin; and when it is thought to be sufficiently tinned, it is taken out and rubbed with sawdust or bran, to clear it from the tallow or pitch with which the surface of the melted tin is covered, and which of consequence sticks to the surface of the tinned iron. If the iron subjected to this process be in very thin plates, the tin will not barely adhere to its surface, but penetrate through it, and combine with all its parts: and on cutting or breaking it, the same white colour will appear in the midst as on the surface of the plate: From which it appears, that white iron, properly prepared, is actually a chemical combination. Besides, it is more malleable than iron, and is wrought into vessels of a form which it would be impossible to make the pure metal take with the hammer.

We have seen in the beginning of this chapter, that iron easily absorbs coal by heat; forming by its union with that combustible body cast iron and steel; with this difference between these two compounds, that in the former it contains oxigene, but not in the latter. In both, the quantity of the iron is much above that of the coal. Scheele, who has applied chemical analysis to so many happy purposes, found, on investigating by this method the nature of *plumbago*, a species of mineral, the rank and character of which naturalists were long at a loss to determine, that it is nothing but

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a natural combination, consisting of a large quantity of coal, with a very small proportion of iron.

Plumbago has been long confounded with *molybdena* *. Pott was the first who proved that neither of these substances contains lead, as they were anciently thought to do. The names bestowed on *molybdena* and *plumbago* were formed to perpetuate the error. They were both indifferently called *lead ore*, *English pencil*, *marine lead*, *black ceruse*, *painter's mica*, *lead pencil*, *false galena*, *talc*, *blende*, *potelot*.

Native *carbure of iron* (a name which, as expressive of the nature of the compound, we have substituted instead of *plumbago*) is found in mountains, frequently among beds of quartz, feldt-spar, clay, or chalk, in the form of irregular round lumps, or balls, like the testicles of animals of various sizes; the largest weighing from eight to ten or eleven pounds; sometimes, too, it is scattered in much smaller fragments; and sometimes even in strata or layers. The inhabitants of Bleoux, a hamlet near Curban, in the higher part of Provence, work *native carbure of iron*, or *plumbago*, which is found in strata of the thickness of four feet, between two beds of clay; the matter is sold at Marseilles. M. de la Peyroux reckons carbure of iron among the minerals of the Pyrenees: it is found in Spain and in Germany; in the Duchy of Cumberland in England there is a very rich mine of it; it is made into pencils which are much esteemed. North America, and the Cape of Good Hope likewise afford specimens of this substance. *Plumbago* has for some time been found in octohædral crystals.

Carbure of iron is of a glistering blackish blue colour;

* It is now agreed, that the substance called *molybdena*, is the oxide of a certain acidifiable semi-metal. Its history has been given among the semi-metals.

lour; it feels greasy, and its fracture is tuberculous; whereas *molybdena* has a lamellated fracture. Its being of an unctuous soapy nature, has induced some chemists to consider it as a kind of impure clay. It spots the hands; and the *black pencil* leaves, as every body knows, a blackish mark on paper.

Carbure of iron suffers no alteration from heat in close vessels. M. Pelletier, who has made a series of experiments on this substance, since Scheele, without obtaining, however, any different result, exposed 200 grains of it in a well-stopped crucible of porcelain to the heat of the fire used in the Sèvres manufactory for porcelain; the mineral lost only 10 grains: But when heated in contact with air, it burns and is oxidated so as to leave scarce any residue. Messrs Quist, Gahn, and Hielm, observed, that 100 grains, treated in this manner in a capsule under a muffle, left only ten grains of ferruginous oxide. This oxidation is a slow combustion, very difficult to bring about. It does not succeed in a common crucible; but to effect it, a thin piece of carbure of iron must be exposed in a broad flat vessel to the action of a strong fire, and the surfaces often cleared, and its position changed.

Neither air, water, nor any earthy substance, acts on carbure of iron. The alkalis act powerfully on this substance. If one part of carbure of iron with two of dry caustic fixed alkali, or the *lapis causticus*, be heated together in a retort with a pneumato-chemical apparatus, the small quantity of water still contained in the salt contributes to the combustion of this substance; a product of carbonated hydrogenous gas is obtained; the alkali is found to be saturated with carbonic acid; and there remains scarce any of the carbure of iron. The result of this experiment, and the detonation of carbure

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carbure of iron with nitre, which will hereafter come under our notice, led Scheele to consider this matter as a kind of sulphur formed of *aerial* or carbonic acid and phlogiston. We will examine this theory, after having considered the other phenomena which this combustible body displays when exposed to the action of acids and neutral salts.

The sulphuric acid, according to Scheele, is incapable of acting on carbure of iron. M. Pelletier has observed, that when 100 grains of this substance and four ounces of concentrated sulphuric acid are digested together cold for several months, the acid acquires a green colour, and becomes liable to congeal by a very moderate degree of cold. This acid, when distilled on carbure of iron, passes into the state of sulphureous acid in consequence of the combustion of a part of that substance.

The nitric acid produces no alteration upon it. The muriatic acid dissolves the aluminous earth and the iron, and serves to purify it, according to M. Berthollet. M. Pelletier has made use of the same process in order to obtain pure carbure of iron. With respect to the aluminous earth which the muriatic acid carries off from carbure of iron, Scheele remarks, that the aluminous earth separated in his analysis belonged to the crucible in which he had before treated it.

Carbure of iron, when melted with four parts of sulphate of potash or sulphate of soda, affords alkaline sulphures, and is entirely decomposed.

Nitre detonates with the help of this substance; ten parts of that salt are requisite to burn one of carbure of iron. The fixed alkali which remains after this operation gives a lively effervescence with acids, and is found to be mixed with a small quantity of oxide of

iron. The same effect takes place with nitrate of soda and ammoniacal nitrate. M. Pelletier has observed, that in this last operation there is ammoniac disengaged in combination with a portion of carbonic acid.

Carbure of iron acts neither on muriate of potash nor muriate of soda.

When distilled with ammoniacal muriate, it gives *martial ammoniacal flowers*. When it is heated with sulphur in a retort, the sulphur is sublimed by itself, without producing any alteration on the carbure of iron.

All these facts concur to prove, that this substance is neither earth nor lead ore, as it was thought to be. But Scheel's theory again, who considers it as a combination of carbonic acid with phlogiston, cannot be admitted, 1. Because that chemist has not informed us what quantity of the acid he obtained; 2. Because he could not compose *plumbago* artificially, by combining carbonic acid with a combustible matter. Besides, the two substances with which Scheele changed carbure of iron into carbonic acid, effect the change by affording vital air, which combines with the inflammable matter of this substance, and gives rise to that acid by the fixation of oxigene; for in this manner does the nitric acid convert tungsten, arsenic, and sugar, into acids. With regard to caustic fixed alkali, which likewise changes carbure of iron into carbonic acid, this effect is plainly owing to the water which that alkali always contains, and which burns the combustible matter in the same manner as it consumes zinc and iron; the hydrogenous gas obtained during the reaction of the alkali and the carbure of iron adds confirmation to this theory.

ry. It might be still farther confirmed by passing water in vapours upon this substance made red hot in a copper or porcelain tube, as is done with iron and zinc. Although this experiment has not been yet made, I believe I may venture to advance, that the whole of the carbure of iron would be destroyed and converted into carbonic acid, and that the product of the operation would be carbonated hydrogenous gas, mixed with a large proportion of carbonic acid. It would then seem a natural inference, that the carbonic acid is a compound of plumbago and oxigene: but as we know from many other experiments, that this acid cannot be formed unless when a combination of coal with oxigene takes place; we must infer, in this instance, that *plumbago* contains a large proportion of coal, and even consists almost entirely of that combustible body. A few facts concerning the properties of coal, here thrown together, will farther confirm this assertion.

The coal of various vegetable matters is brilliant, and has a metallic aspect, like carbure of iron: it soils the hands, and marks paper like that matter; and its texture too is granulated and brittle. The most brilliant coals, such as those of some animal substances, are as difficult to burn as carbure of iron, which needs to be much stirred, exposed to an intense heat, and brought as much as possible into contact with air, in order that it may be consumed: iron is found in both: And lastly, these two substances are both liable to be changed into carbonic acid by combustion. After considering these facts, may we not regard *plumbago* as coal formed in the interior parts of the globe, or buried in the earth? May we not even conclude, that this matter is formed by the combination of some mineral principles?

ciples? though almost all chemists be of opinion that nothing but organic matters can be converted into coal. But this notion can be confirmed or refuted only by a regular inquiry into the state of carbure of iron in nature, the circumstances of its formation, and the alteration which it suffers. Since the researches of Messrs Vandermonde, Monge, and Berthollet, into the several states in which iron subsists, discovered these facts concerning carbure of iron, they have farther discovered, that there is constantly formed, on the fusion of cast iron, a substance precisely similar to native carbure of iron. The ladles with which the cast iron is taken out to cool are usually coated with it. Masses of it are likewise found in crystals in repairing the upper parts of the furnaces. We may venture to hope that it will be one day artificially prepared for the service of the arts.

Carbure of iron is a good deal used. It is made into pencils; the most esteemed of which come from England. Reswick, in the Duchy of Cumberland, is the place where that used for pencils is found. The native lumps are sawed into small slender pieces; which are put into wooden cylinders with grooves, so cut that the cavity of the cylinder may be entirely filled. The dust produced from the sawing and cutting of the pieces inserted into the cylinders is used for pencils of an inferior quality, a great many of which are sold at Paris. It is mixed with a gum paste, or melted with sulphur. These base pencils are known in England, either by their melting and burning at the flame of a taper, or by their separating into bits, and even falling into powder when steeped in water. The German carbure of iron is likewise used for pencils: in making

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them several extraneous matters are added; such as coal, sulphur, &c. In England the finest dust of carbure of iron is used for coating the wheel-work of some instruments; and it facilitates their motions by its greasy unctuous nature.

One of the most important uses to which this substance is applied is to coat iron, in order to preserve it from rusting; the pipes of stoves, the back parts of grates, and other utensils exposed to the action of fire and air are coated with powder of carbure of iron, which is applied to their surface by simply rubbing with a brush. Homberg, in the year 1699, described a process for giving a leaden colour to utensils of iron. It consists in mixing eight pounds of melted animal fat with four ounces of camphire, and a sufficient quantity of carbure of iron, and laying this composition on iron so hot that it can scarce be held in the hand: these utensils must be carefully wiped with a cloth, after being covered with this sort of varnish.

The workmen who manufacture lead for hunting-shot, soften and blacken its surface at the same time by rolling it in powder of carbure of iron. It is likewise a part of the composition put upon the pieces of leather used for strapping razors. Lastly, it is used in the manufacture of several black English earthen wares; and in that of the crucibles which are made at Passaw in Saxony.

M. Pelletier, who has given a good account of the various uses to which carbure of iron is applied, found it to answer very well in a luting which he prepared after Pott, with one part of this substance, three of common clay, and a little cow-dung reduced very small. This luting supports glass retorts well enough: they even melt sometimes without its suffering any change of form.

The principal uses of iron are so extensive, and besides so well known, that it is unnecessary to insist on them here; only we may mention, that no art can do entirely without it, and that it is, as Macquer says, the soul of all arts. The various modifications of which it is susceptible, render it very suitable for all the purposes to which it is applied. Cast iron is run into utensils more or less solid, and capable of resistance, according to the purposes for which they are designed. The tenacity and hardness of the several species of forged iron render it very suitable for all the purposes to which it is applied. The same is the case with the several kinds of steel. The fineness of the grain and the temper vary so as to divide it into a great many species, each of which is better fitted than any of the rest to some purpose or other in the circle of the arts. Oxides of iron serve for giving a red or brown colour to porcelain, pottery, enamels, &c. They are likewise employed in the preparation of artificial precious stones; and mixed with oil for painting colours.

Iron affords a remedy of great use in medicine; to which indeed the art is indebted for most part of its success. This is the only metal that has no noxious quality whatever, and of the good effects of which there can be no doubt. There is even, as we have seen, such an analogy between iron and organic matters, that it seems to compose a part of them, and to be often produced by the operation of the vital powers of animals and by vegetation. The effects of iron on the animal œconomy are various. It stimulates the fibres of the membranous viscera, and appears to act more especially on those of the muscles, which it affects as a tonic. It fortifies the nerves, and communicates to the animal,

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when enfeebled and languid, new force and vigour in a remarkable degree. It excites many secretions, especially such as take place by evacuations of blood or urine. It contributes to bring on natural hæmorrhages, such as the menstrual flux and the hæmorrhoids. It increases and multiplies the contractions of the heart; and of consequence renders the pulse quicker and stronger. It acts with no less energy on the fluids. It passes easily into the channels through which the blood circulates, combines with it, and thus gives it new density, consistency, and colour, and renders it more liable to concretion. It at the same time communicates to it such activity, that it passes without difficulty into the smallest vessels, stimulates of itself the sides of the ducts through which it flows; and thus conveys life and vigour through the whole system. The valuable experiments of M. Menghini, published among the Memoirs of the Institution of Berlin, prove, that the blood of people who make use of iron is higher coloured, and contains more than the natural quantity of this metal. Lorry, who in the practice of medicine has displayed that nice acuteness of observation, and that extension of views which distinguish the profound and philosophical physician; observed the urine of a sick person to whom he had administered iron reduced to powder, to have the colour of nut-gall. This metal is therefore tonic, strengthening, stomachic, diuretic, alterative, incisive, and to it a great many medicines owe those properties which render them useful. It contracts the fibres like astringents, it increases their oscillation; and it has the superiority over many of the other medicines which possess the same virtues, as being more constant and durable in its effects; for it combines with the organs themselves, by means of the fluids by

which these are nourished. It may be usefully administered therefore in all cases in which the action of the fibres of the viscera of the muscles, or even of the nerves, is very feeble; when the stomach and intestines are so languid as to refuse their functions; and in the case of weakness arising from such a cause; in short, whenever the consistency of the fluids is diminished, and they are become too thin, as in the green sickness, and in tendency to dropsy, &c. It is used under many different forms; such as levigated filings, martial Æthiops, astringent and aperitive saffron of Mars, Stahl's alkaline martial tincture, martial flowers of sal ammoniac, &c. To these medicines there might perhaps be added iron precipitated from acids, and again dissolved by ammoniac. Prussian blue, the use of which as a medicine is proposed by the chemists of the Academy of Dijon, &c. Sulphate of iron is applied externally to stop hæmorrhages, &c.

Iron, endowed with magnetic qualities, or artificial loadstone, has been thought to produce some very singular effects on the animal œconomy. According to many modern authors, when laid upon the skin, it eases pain, stops convulsions, occasions redness, sweating, and often too the eruption of small pimples; it likewise renders epileptic fits less frequent. We are even assured, that in the space of twelve hours it communicates to water a purgative quality. These assertions, which are justified by facts, afford so many proofs to enlightened philosophers of the difficulties with which the study of animal physics is attended. As no body is liable to be affected by the magnetic powers of other bodies which is not itself capable of acquiring such powers, it must therefore be impossible for the loadstone to act by virtue of its magnetic powers upon the animal œconomy.

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The physicians who ascribe to it such eminent effects and such energetic medicinal powers, have been misled and deceived by the changes, more or less sensible, which have taken place about the time of the application of the magnetic body, and have been owing to the circumstances of the case and the happy exertions of nature. This opinion is farther enforced by considering, that nature seems to act with more irregularity and inconstancy in removing pains and convulsions than in any other instance; and that the medicinal virtues of the loadstone are chiefly inferred from the effects which have followed after applying it in cases of this kind..

C H A P.

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Of Copper.

COPPER is an imperfect metal, of a very brilliant red colour, to which the alchemists gave the name of *Venus*, on account of the readiness with which it combines so as to suffer alteration from a vast variety of other bodies. It has a disagreeable smell, which is felt when it is rubbed or heated. Its taste is stiptic and nauseous, but less sensible than that of iron. It is hard, very elastic, and very sonorous. Its ductility is considerable: it is reducible into very thin plates and very slender threads. In the hydrostatic balance, it loses about an eighth or a ninth part of its weight. Such is its tenacity, that a thread of copper, one-tenth of an inch in diameter, supports 299½ pounds weight without breaking. Its fracture appears as if it were composed of small grains. It is susceptible of a regular form. The Abbé Mongez defines its crystals to be quadrangular pyramids, sometimes solid,

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Copper is found in various states in the earth. Its ores are very numerous; but they may be all reduced to the following.

1. Native copper of a red colour, malleable, and possessed of all the other properties of the metal. It is distinguished into two sorts; copper of the first formation, and copper of a secondary formation or cementation. The copper of the first formation is dispersed in plates or filaments within a gangue, which is almost always of a quartzose nature. It is sometimes found in octahædral crystals, one above another, resembling a kind of vegetation. There are other specimens in masses and grains. Copper of cementation is commonly in grains, or in thin laminæ on the surfaces of stones or iron. That which is found on iron appears to have been deposited in waters containing sulphate of copper, and precipitated by iron. Native copper is found in many places over Europe: At St Bel, in the neighbourhood of Lyons, at Norberg in Sweden, at Newfol in Hungary, and in several parts of America *.

2. Copper oxidated and mineralized by the carbonic acid. There are several varieties of native carbonate of copper.

Varieties.

A. Red copper, or *hepatic copper ore*. This ore is distinguished by its dark red colour, like the colour of the scales which fall off from copper made red hot, and then struck with a hammer. M. Monnet considers this ore as a
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* Also in different places in England, Scotland, and Wales.

Varieties.

natural oxide of copper. It is generally mixed with native copper and *mountain green*: it is not very plenteous; sometimes it is found in octahædral crystals, or silky fibres called *flowers of copper*.

- B. *Earthy copper, mountain green, or green chrysocola.* This ore is a genuine oxide of copper, of a lighter or a deeper green, not heavy, and unequally dispersed within its gangue. It appears from the analysis of the malachite, made by the Abbé Fontana, to be combined with carbonic acid. This ore is sometimes very pure. It may be considered as existing in three different states.

Simple *mountain green*, earthy or impure, called also *green chrysocola*.

Mountain green in crystals, or *silky copper* of China. This ore, which is common enough in Vosges and Hartz, is likewise found in China. It is pure, and crystallized in long silky bundles of no small solidity.

Mountain green in stalactites, or *malachite*. This substance, which is found in considerable abundance in Siberia, consists of layers in the form of nipples, of various sizes: some of the specimens consist of needles converging towards a common centre. The different layers have not all precisely the same shade of green. The malachite is hard enough to take a fine polish; and various toys are made out of it; but as it is often porous, and full of unequal cavities, the solid pieces are always

Varieties.

the most valuable when they come up to a certain size.

C. *Mountain blue*, or *blue chrysocolla*. This is an oxide of copper of a deep blue colour; it is sometimes in a regular form, and in rhomboidal prismatic crystals of a very beautiful blue. It is then called *copper azure*. At other times it is found in small grains deposited in the cavities of different gangues, more especially in quartz. Generally, however, it is in thin layers, in the cavities of grey and yellow copper ores. It appears that all these oxides of copper have been precipitated from sulphuric solutions of this metal by the intermedium of calcareous earths, through which the waters containing them flow. M. Sage considers these blue copper ores as combinations of copper with ammoniac; and says that they differ from it only in being insoluble. He likewise thinks that the malachite is nothing but this blue, which he calls transparent azure copper ore, with a small alteration. But this opinion is not generally received among mineralogists. M. de Morveau thinks that the blue differs from the green oxide of copper only in containing a smaller proportion of oxigene.

The blue oxide of copper seems to be the matter which colours certain stones; the turquois stone particularly, in which Reamur found copper, appears to owe its colour to this cause, as well as the Armenian stone, the base of which is calcareous carbonate, or sulphate

Varieties.

fulphate of lime. Mr Kirwan makes a species of copper ore of these blue stones. The turquois is formed of animal bones, coloured by copper. According to Reaumur, the Persian turquois is not liable to suffer from the attacks of the nitric acid. The same acid entirely dissolves the turquois of Languedoc.

3. Copper mineralized by the muriatic acid and combined with clay. M. Werner speaks of this ore in his translation of Cronstedt. It has been confounded with talc; and a person of the name of *Dans* exposed it to sale at Paris in the year 1784, under the name of *green mica*. It is in small crystals of a beautiful green colour, or in small sparkling scales. Mr Forster found specimens of this in the mines of Johan Georgenstadt. The green copper sand brought from Peru by M. Dombey seems to belong to this species of copper ore: on analysing it, I have found it to contain a little muriatic acid.

4. Copper mineralized by sulphur almost without iron. It is called *vitreous copper ore*; but the name is very improper. It is dark grey, violet, brown, greenish, or entirely brown and liver-coloured. A very moderate heat melts it. It is ponderous, sometimes flexible, and always of such a consistency that it may be cut with a knife. In its fracture it appears brilliant like gold. It is one of the richest copper ores; for it affords no less than 90 pounds of copper in the hundred weight.

5. Copper mineralized by sulphur with more iron than is contained in the species immediately preceding; azure copper ore. It differs from the last only in containing

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taining about 30 pounds to the hundred weight : it affords only from 50 to 60 pounds of copper in the hundred weight ; the rest is sulphur. These two ores may be assayed by acids.

6. Copper mineralized by sulphur with a good deal of iron ; brilliant or yellow golden pyrites. The quantity of the sulphur and the copper varies greatly in this ore ; the iron is always in a very considerable proportion. It exists in the earth in veins more or less considerable. This ore is sometimes massy and dark, often scaly, and seemingly micaceous. Such is the form of that of Denmark, Norway, Sweden, and St Marie-aux-Mines. On other occasions this ore is dispersed in its gangue, as the copper of Alsace ; it is then called *speckled copper ore*. This variety is often mixed with a little azure ; coppery pyrites exhibit very brilliant colours on their surface, either blue or violet, which are owing to the decomposition of their principles. They are then called *copper with a waving light*, or *peacock-tail copper ores*. They usually contain a great quantity of sulphur, a little iron, and in copper they are not very rich. When these ores are only superficially dispersed on the gangue, they are more particularly distinguished by the name of *copper pyrites* : Of which kind are the ores of Derbyshire in England, some of those of St Bel in the Lyonnois, and a number in the mines of Alsace, as at Caulenbach and Feldens. They are besides found adhering to gangues of all sorts, rock crystal, quartz, spar, schistus, and mica, &c.

7. Copper united with sulphur, iron, and a little silver. This ore is called *arsenical copper ore*, or *fablertz*, and bears a great resemblance to the grey silver ore ; only it is not just so brilliant ; the only difference is, that this copper ore contains less silver than the
3 other.

other. M. Romé de Lille takes notice likewise of a white copper ore, which according to him contains a little more silver than the grey: but that is a true silver ore. Fahlertz affords from 35 to 60 pounds of copper in the hundred weight.

8. Copper mineralized by sulphur and arsenic, with zinc and iron. *Brown, or blendy copper ore.* M. Monnet found this ore no where but at Catharineberg in Bohemia: it is brown, granulated, and very hard. It contains from 18 to 30 pounds of copper in the hundred weight.

9. Schistous copper ore. This is *vitreous copper* very intimately mixed with brown or black schistus. It affords from 6 to 10 pounds in the hundred weight: chalk must be added when it is melted.

10. Bituminous copper ore. This is copper mixed with a kind of coal of Swedish earth.

11. Black, or pitch-coloured copper ore. M. Gellert calls it *copper ore in scoræ*: it is a residue, remaining after the decomposition of yellow and grey copper ores, which contains neither sulphur nor arsenic, and is nearly in the state of *malachite*. It is of a glistering black colour like pitch.

12. Copper combined with sulphur and arsenic, containing antimony. *Antimonial copper ore.* M. Sage mentions this ore in his Elements of Mineralogy. It is grey and brilliant in its fracture like antimony. It contains from 14 to 20 pounds of copper in the hundred weight.

To assay a copper ore, after being pounded and washed, it must be subjected to long roasting by an intense heat, and melted with four times its own weight of black flux and marine salt. The button thus obtained, which is often blackened with a residue of the sulphur,

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is next to be melted with four parts of lead, and passed into a cupel, where the silver and gold which it contains may be separated; for there is but very little copper which does not contain some portions of these precious metals. M. Tillet's flux, which is a mixture of two parts of pounded glass with one of calcined borax, and an eighth of coal, succeeds better in reducing this metal than black flux; for the black flux forms an alkaline sulphure, which dissolves a part of the oxide of copper.

Bergman recommends the sulphuric and the nitric acids for assaying copper ores in the humid way. When the copper is dissolved by the acids, it is then precipitated by iron.

In working copper ores in the great way, they are first pounded and washed: they are then roasted at the first in the open air, and almost without wood; for when the sulphur which they contain is once kindled, it burns away of itself. When it ceases to burn, the ore is then roasted anew, and even twice successively on wood, in order to obtain what is called *the mat of copper*. This is the ore after it has lost only a portion of the sulphur which it contained. The fusion to which it is subjected serves to make it expose its surfaces more entirely to the heat; in consequence of which it is more thoroughly roasted. It is exposed to six or seven successive roastings, according as it contains more or less sulphur, and is then melted into *black copper*. This copper is malleable: still, however, there is so much copper united with it, which cannot be separated without extracting at the same time the imperfect metals which it contains. The black copper is melted with three times its quantity of lead, which is called *refreshing the copper*; and this mixture is moulded into the

form of loaves, which are called loaves of *eliquation*. These are instantly placed on two plates of iron, inclined so as to leave a gutter between them. They terminate immediately over the furnace of *eliquation*; the under part of which slopes forward. The fire under the plates heats the loaves: the lead melts, and runs under the coals, carrying with it the silver and the gold, with which it has a greater affinity than with copper. After this operation, the cakes are found to be considerably diminished, and to have lost their shape. They are now exposed to a stronger fire; the heat of which is so intense as to melt the copper so far that it may be entirely separated from the lead. This third operation is called (in French) *ressuage*. The lead, with the perfect metals, is taken to the cupel. As to the copper, it is refined by melting it in a crucible, and suffering it to stand so long melted that it may throw up in a scum any extraneous matters which it contains. It is assayed by dipping into it iron rods, which take up a little copper; and from its being more or less of a bright red colour, a judgment is formed of the purity of the metal. Copper thus refined is run into plates, or divided into *rosettes*. To form a *rosette*, the scoriæ with which copper in fusion is covered are carefully taken off. The surface of the metal is suffered to settle and fix: when it ceases to be fluid, it is swept over with a besom: The impression of cold contracts it. The portion congealed separates not only from the edges of the crucible, but likewise from the rest of the melted metal, and is taken off with pincers. Most part of the copper in the crucible is thus taken off in *rosettes*. What remains at the bottom is called *the king*.

Cupreous pyrites, containing but little of the metal,

are

are wrought solely for the sulphur and the vitriol. At St Bell, and in many other places, they are roasted and distilled, in order to separate the sulphur. During the roasting a portion of the sulphuric acid acts on the metal, dissolves it, and thus begins to form sulphate of copper. The roasted pyrites are next exposed to the air; and when the *vitriolization* is ended, the pyritous efflorescence is lixiviated, the lixivium filtrated and evaporated, in order that it may afford a blue rhomboidal salt in crystals, called *vitriol of copper*, *blue vitriol*, *blue copperas*, or *vitriol of Cyprus*. We will speak of it when we come to examine the combinations of this metal, under the name of sulphate of copper.

Copper, when exposed to fire, takes nearly the same colours with steel: it becomes first blue, then yellow, and at last violet. It does not melt unless when very red. When fully in fusion, it appears covered over with a green flame: it boils, and is capable of volatilization, as may be observed in the chimnies of foundries. There are also found flowers of copper in the crucibles in which it is melted. Small filings of this metal, when thrown into the flames, give them a blue and green colour. It is used in artificial fire-works, on account of this property. If this melted metal be slowly cooled, and the fluid portion decanted off, that which adheres to the sides of the crucible or roasting pot employed in the experiment is found in pyramidal crystals; which are larger and more regular in proportion as the fusion of the metal is more complete, and its cooling more slowly brought on. The pyramids are quadrangular, and appear to consist of a number of octahedrons disposed one over another.

Copper heated in contact with air, burns at the surface, and changes into a blackish red oxide, as it ab-

forbs the base of vital air. This oxide may be easily obtained by making a copper plate red hot, and then striking it with a hammer; the oxide comes off in scales. The same thing takes place when a copper plate is dipped in cold water after being made red hot. The sudden contraction of the parts of the metal contributes to the separation of the oxide which covers its surface. The oxide falls to the bottom of the water; it is called *scales of copper*. As the copper is not completely oxidated, it may be burnt anew under the muffle of a cupelling furnace; it then takes a pretty deep brown colour; when urged with a violent heat, it melts into a blackish or brown chefnut-coloured glass. Oxide of copper may be decomposed and deprived of its oxygen which destroys its metallic properties, by oils, resins, &c. The scales are in part reducible by themselves; for founders buy them from copper-smiths, and use no means for their reduction but throwing them into large crucibles above melted copper, with which, as they melt, they enter into union. The filings of this metal are melted in the same way. Oxide of copper appears to possess some saline properties; but its nature, as a salt, has not yet been the subject of examination.

Air acts upon copper; and the more easily the more it is loaded with, and altered by moisture. It converts it into a rust or green oxide, which appears to have some saline properties: it has a taste, and is liable to be acted upon by water. Such was the reason which induced the ancient chemists to consider copper as containing a salt. One thing remarkable with regard to this salt is, that it never penetrates deeper than the surface, and seems to contribute to the preservation of the interior parts of a mass of this metal; as may be inferred from

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from the state of ancient medals and statues, which are well preserved under the coat of rust with which they are covered. Antiquaries call that rust *patina*, and set an high value on it; because it is a proof of the antiquity of those pieces which are covered with it. There are many artists, especially Italians, who know how to imitate this rust on copper; and thus counterfeit ancient pieces of bronze.

The oxidation of copper by humid air appears to be owing to water in a state of extreme division. This fluid, however, does not appear to attack copper in the same manner as iron at an high temperature. It would rather seem, that cold water oxidates the metal; for it is known to be more dangerous to leave liquors to cool, than to boil them in copper vessels. When the liquor is boiling, and the vessel hot, the aqueous vapour does not attack the surface of the metal; but when the liquor is cold, the drops which adhere to the sides of the vessel appear to reduce the copper to green oxide. This oxidation may be therefore ascribed, with great probability, to the operation of the air, and the carbonic acid diffused through it: for, on distilling this rust of copper in a pneumat-chemical apparatus, I obtained from it carbonic acid.

Copper does not combine with earthy matters. Its oxide, however, contributes to their fusion, and combines with them to form brown glasses of a lighter or a deeper shade.

Barytes, magnesia, and lime, act not in a discernible manner on copper: we know not how they act on the oxide of this metal.

Caustic fixed alkali, digested cold with filings of copper, assumes in a certain time a very light blue shade; and the copper is covered over with a dust of the same

colour. According to M. Monnet, these solutions are better effected in cold than in heat. It is, however, of importance to observe, that he made the combination with carbonate of potash, not with pure fixed alkali. Pure fixed alkali seems to have much more influence on copper: But neither of these salts does any thing more than promote and hasten the precipitation of the oxigene of the atmosphere into copper; for the oxidation never takes place without the concurrence of air.

This phænomenon is more especially remarkable when ammoniac is brought into contact with copper; on which occasion the metal is pretty soon dissolved. When ammoniac is digested on filings of copper, with concurrence of air, it takes, in a few hours, a very beautiful deep blue colour; there is not, however, much of the copper dissolved. I have for a year observed the phænomena of this solution. I put into a small phial a portion of caustic ammoniac with copper filings; the phial was often unstopped. At the end of some months I found the surface of the metal covered with a blue oxide: its sides were coated with a pale blue oxide; and the under part of the phial, containing the copper, displayed at the surface of the glass a brown oxide, the upper part of which was yellowish. When the phial containing this liquor is closely stopped, the liquor loses its colour almost entirely; but whenever the phial is unstopped, it appears again. It does not exhibit this phænomenon in an eminent degree, except in the beginning of the operation, and when it is decanted from above. If the solution be not newly made, and still contain copper, it is of a beautiful blue colour even in close vessels: however, when exposed to the air, its colour becomes still deeper. These phænomena show the influence of the oxigene of the atmosphere.

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When the solution of copper by ammoniac is slowly evaporated, most part of the salt is dissipated ; a portion, however, remains fixed with the oxide of the metal, and is deposited in soft crystals ; as has been observed by M. Monnet. M. Sage asserts, that very beautiful crystals may be obtained from this solution by slow evaporation ; and compares them to natural azure of copper. This last substance, however, affords no ammoniac when heated ; is not soluble in water ; and does not effloresce in the air, like that which is artificially prepared. M. Baumé says, this compound forms very brilliant crystals of a very beautiful blue colour. This solution, when exposed to the air, becomes very soon dry ; and what remains is a matter of a grass-green colour, which can be nothing but a green oxide of copper. M. Sage thinks this the origin of the malachite : but this oxide does not afford near so much carbonic acid as the malachite. An acid poured into the solution of copper by liquid ammoniac produces scarce any precipitate, but changes the blue colour of the solution into a very light pale green. This phenomenon, which has been observed by Messrs Pott and Monnet, shows that there is but very little oxide of copper in the ammoniac, and that it is again dissolved by the acid, or by the ammoniacal salt, formed by the addition of the acid. By adding ammoniac to the mixture, however, it may be made to resume its blue colour. Both the oxide of copper reduced to that state by fire, and all the other oxides of this metal, are instantaneously dissolved in pure ammoniac ; and the salt may be thus impregnated with a considerable portion of the metal. It takes immediately a very beautiful blue colour : and, on this account, it has been proposed to use it as a test for ascertaining the presence or ab-

sence of copper in substances in which it may be suspected to exist.

The sulphuric acid does not act on copper except when concentrated and boiling : a good deal of sulphureous gas is disengaged while this solution takes place. When the solution is completed, the two substances are found to have formed a matter of the consistency of jelly, containing oxide of copper by itself, and a portion of that oxide in combination with sulphuric acid. By lixiviating this matter and filtrating the lixivium, a blue solution is obtained : when evaporated to a certain point, and suffered to cool, this solution affords oblong rhomboidal crystals of a beautiful blue colour, which are sulphate of copper. If, instead of being evaporated, this solution be left for a long time exposed to the air, it affords crystals ; but it likewise precipitates a green oxide,—the colour which all oxides of copper take that are either formed or dried in the air.

Sulphate of copper has a very strong stiptic taste ; it is even caustic. When exposed to fire it melts very quickly : it loses its water of crystallization, and takes a bluish white colour. A very strong heat is requisite to separate the sulphuric acid, which adheres much more obstinately to oxide of copper than to oxide of iron. Sulphate of copper is decomposed by magnesia and lime : the precipitate formed by either of these substances is of a bluish white colour : when dried in the air it becomes green ; on this account chemists describe the precipitates of sulphate of copper as green. The case is absolutely the same with those which are obtained by fixed alkalis in different states ; they are at first bluish, and take a green colour when dried : perhaps *mountain green* may be formed in this manner. It is of consequence to observe, that when sulphate of copper is precipitated by a solution of carbonate of pot-

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ash, there is no effervescence excited; a circumstance which proves that the carbonic acid unites very readily with oxide of copper. This phenomenon is not common to all solutions of metals. Ammoniac in the same manner causes sulphate of copper to yield a bluish white solution; but the mixture soon takes a very deep blue colour; for the ammoniac dissolves in some measure the precipitated copper: and a very little of that salt is sufficient to dissolve again the whole of the copper separated from the sulphuric acid.

The nitric acid dissolves copper cold, and with rapidity. A good deal of very high-coloured nitrous gas is disengaged from this solution. This method Dr Priestley employed in order to obtain this gas very strong. A portion of the metal reduced to oxide is precipitated in a brown powder, and separated from the solution by filtration. This solution, after being filtrated, appears of a much deeper blue colour than the solution of copper by the sulphuric acid; which shows that the copper is here more completely oxidated. This solution, carefully evaporated, crystallizes by cooling. Macquer, in his memoir on the solubility of salts in alcohol, is one of the first chemists who observed this fact. If the crystals are very slowly formed, they become oblong parallelograms; if deposited more quickly, hexahedral prisms, the point of which is obtuse and irregularly formed, and which appear like bundles of divergent needles. Lastly, when this solution is too quickly evaporated, it affords only a magma of no regular form. This, no doubt, is what has made chemists say, that the solution is not susceptible of crystallization. Nitrate of copper is of a very bright blue colour. It is so caustic, that it may be applied to corrode excrescences growing on the skin. It melts, according to M. Sage, at a temperature of twenty degrees of Reaumur's thermometer.

thermometer. It detonizes on burning coals; but as it contains a good deal of water, the phænomenon is not very discernible. When melted in a crucible it exhales a good deal of nitrous vapour, which may be collected by distilling it: when dried, its colour is green: when still farther urged with heat, it becomes brown: it is now nothing but pure oxide of copper. I have distilled a quantity of it in a pneumat-chemical apparatus, and it afforded a good deal of nitrous gas, a little carbonic acid, and a little vital air: by this operation it was reduced into the state of brown oxide. Nitrate of copper attracts the moisture of the atmosphere. It may, however, be preserved for a long time in close vessels. When exposed to a hot dry air, it is covered over with a green efflorescence. It is very soluble in water, and rather more soluble in hot than in cold water. The solution, if exposed to the air in flat vessels, or hastily evaporated in dry warm weather, leaves a green oxide, such as the crystals of the salt leave on a similar occasion. Lime makes it yield a pale blue precipitate; fixed alkali, a bluish white precipitate; by ammoniac it yields flakes of the same colour, which are very quickly dissolved; and communicate to the liquor a very bright deep blue tincture. Its precipitate by alkaline sulphures is of a brownish red colour, without a foetid smell; with the tincture of nutgall it gives an olive green precipitate. The sulphuric acid likewise decomposes nitrate of copper; and if it be employed in an highly concentrated state, crystals of sulphate of copper are obtained. Stahl first took notice of this decomposition; M. Monnet has since confirmed the fact related by Stahl; and I have several times had occasion to observe it. Iron has a greater affinity than copper with most of the acids. When a plate of this metal is immersed into a solution of copper

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by the nitric acid, the copper is precipitated in a metallic form, and colours the surface of the iron: the iron effects this precipitation in consequence of its having a stronger affinity than copper with oxigene. Sulphate of copper displays the same phænomenon; and jugglers, by this process, make ignorant people believe that they can change iron into copper.

The muriatic acid dissolves copper only when concentrated and boiling: only a very little hydrogenous gas is disengaged when this solution takes place. The muriatic acid takes a very deep green, almost a brown colour. This combination forms a magma, which dissolves readily enough in water: if this magma be lixiviated, the water is of a beautiful green colour; a circumstance which serves to distinguish this from the two preceding solutions. On evaporating it slowly, and suffering it to cool, it deposits prismatic crystals sufficiently regular, if the evaporation have been cautiously managed; but if the evaporation have been too quick, and the cooling too sudden, they then appear under the form of very small sharp needles. Muriate of copper is of a grass green colour, very pleasing to behold: its taste is caustic and very astringent; it melts by a very moderate heat, and when suffered to cool, congeals into a mass. M. Monnet affirms, that the muriatic acid adheres to it with great obstinacy, and that a very considerable heat must be applied to volatilize it: it powerfully attracts the moisture of the atmosphere; it is decomposable by the same intermedia which decompose the preceding salts of copper. I have observed, that ammoniac does not dissolve the oxide which it separates from the muriatic acid so readily as that which it separates from the sulphuric and the nitric acids. The blue then formed is not so lively, and there remains

mains a portion of the oxide which the ammoniac does not thoroughly dissolve. Neither the fulphuric nor the nitric acid decomposes muriate of copper. The nitric solutions of mercury and silver decompose it, and are themselves decomposed at the instant of the mixture. A white precipitate is formed in consequence of the muriatic acid uniting with the oxide of mercury or silver; and the oxide of copper combines with the nitric acid. I have however observed, that this liquor does not assume the blue colour which a solution of copper by the acid of nitre ought to have; and that in general, the oxide of copper formed by the muriatic acid, does not assume this colour but with great difficulty, as we have already seen with regard to ammoniac. I have found, that in general oxides of copper pass very easily from blue to green, and with very great difficulty from green to blue. The muriatic acid dissolves oxide of copper much easier than copper itself. This has been observed by Brandt. The colour of the solution is a beautiful green; and it crystallizes as the former: a circumstance which proves, that in saline metallic combinations the metals are always in the state of oxides, as we have already observed.

Nitre detonizes with difficulty by copper. The salt must be in fusion, and the copper very hot, in order that the deflagration may take place: still, however, it is but very weak. This operation is performed by casting copper filings on nitre in fusion into a large crucible, in order that their parts may be as much as possible in contact with each other. When the metal becomes very hot, a slight motion is observed with faint sparklings. The residue is a brownish grey oxide mixed with potash; it is washed; the water takes up the alkali, which still retains a little copper, and the oxide of the metal

metal remains pure. It melts all alone into a deep brown opaque glass; it is used to colour enamels. It is thought that the alkali is rendered caustic; but more experiments are necessary to ascertain this.

Copper very readily decomposes ammoniacal muriate. Bucquet, who examined this decomposition with very great care, obtained, on making the experiment in a pneumato-chemical apparatus with mercury, from two drams of copper filings and a dram of ammoniacal muriate, fifty-eight inches of elastic fluid; of which twenty-six inches were very pure ammoniac, twenty-six inches detonating inflammable gas, and the remaining six inches a mephitic gas, which extinguished lights, without being absorbed by water, or precipitating lime-water; and was consequently azotic gas produced by the decomposition of a part of the ammoniac. There was a little liquid ammoniac disengaged, of a fine colour, which stood immediately over the mercury. The residue was a blackish green mass, one half of which was dissolved in the water, and communicated to it a fine colour, the distinguishing characteristic of muriate of copper: the other half was a kind of brown oxide of copper, formed by the water of the ammoniacal muriate. On repeating this decomposition on four ounces of copper to two of ammoniacal muriate, with the common apparatus of a balloon, Bucquet obtained two drams and eighteen grains of blue liquid ammoniac, which gave a slight effervescence with acids, and contained about an inch of carbonic acid to the dram. He knew not how to account for the appearance of this last gas: but I suppose it might proceed from some impurities of the sal ammoniac; for on repeating the experiment with ammoniacal muriate, previously purified by sublimation, the ammoniac which I obtained was

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very

very caustic, and did not effervesce in the least degree with acids. Oxide of copper likewise decomposes ammoniacal muriate, and communicates to the ammoniac which it disengages a portion of carbonic acid that renders it effervescent. This alkali is always blue, because it takes off with it a small portion of oxide of copper which colours it. Acids, however, do not precipitate an atom of the metal. There are two medicines prepared in pharmacy with ammoniacal muriate and copper; the former of which has received the name of *cupreous ammoniacal flowers*, or *ens veneris*. This is nothing but ammoniacal muriate coloured by a little oxide of copper. A mixture consisting of eight ounces of this salt with a dram of oxide of copper, is sublimated in two earthen pots, the one placed over the other. All the ammoniacal muriate is volatilized without being decomposed; and it carries off with it a little oxide of copper which communicates to it a bluish colour. The second, called *celestial water*, is prepared by putting an ounce of ammoniacal muriate with a pound of lime-water into a copper basin, and suffering the mixture to stand in it for ten or twelve hours. The lime disengages the ammoniac, which dissolves a little of the copper of the basin; and by that means acquires a blue colour. Celestial water may be made in a glass or an earthen vessel, by adding a small quantity of filings or oxide of copper to the lime-water and ammoniacal muriate.

It appears that copper decomposes aluminous sulphate; for when a solution of this salt is boiled in a copper vessel, there is a little aluminous earth precipitated: And when this alum is precipitated by ammoniac, the earth assumes a blue colour, which indicates the presence of copper. This effect may be like-

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wise ascribed to the excess of acid which aluminous sulphate always contains.

Hydrogenous gas does not act upon copper, but reduces the oxides of copper, by robbing them of their oxigene; with which principle hydrogene has a greater affinity than copper has.

This metal combines very readily with sulphur. The combination may be effected in the humid way; that is, by mixing flowers of sulphur with copper filings moistened with water; but it succeeds much sooner in the dry way. To accomplish it in this way, a mixture, consisting of equal parts of sulphur in powder and copper filings, is exposed to fire in a crucible, which is gradually heated till it become red hot; from this combination there results a blackish grey mass, a sort of *mat* of copper, which is brittle and more fusible than copper. This compound is prepared for a tincture, and for painting Indian stuffs, by laying in a crucible alternate strata of copper and sulphur in powder, and heating the crucible in the manner above mentioned. The mat thus formed is pulverized, and receives the name of *as veneris*. Alkaline sulphures and sulphurated hydrogenous gas act in a sufficiently eminent manner on copper. The former substances dissolve this metal either by the dry or by the humid way: the latter communicates an high colour to its surface; but the mutual effects of these substances and copper have not been farther examined.

Copper forms an alloy with various metals: with arsenic it becomes white and brittle, and so forms *white tombac*.

It combines with bismuth; forming with it, according to Gellert, a reddish white alloy with cubic facets.

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It enters very readily into union with antimony, forming with it the *cupreous regulus* distinguished by a beautiful violet colour. It decomposes sulphure of antimony, and combines with the sulphur which it detaches from the semi-metal.

With zinc it combines very readily. This combination may be effected in two ways; 1. By fusion, a metal is obtained of the colour of gold, much less liable to rust than pure copper; but at the same time less ductile. The more this metal resembles gold, the brittler it is: besides, its nature varies according to the proportion in which the two substances are mixed together and the precautions taken in melting them: its varieties are similar, pinchbeck, Prince Robert's metal, and Manheim gold. 2. By cementing plates of copper with native carbonate of zinc, or lapis calaminaris reduced to powder, and mixed with coal, and making the crucible in which they are contained red-hot, the copper then forms *yellow brass*. This last compound is not so liable to rust as copper: it is equally malleable and more fusible; but if exposed for ever so short a time to a strong heat, it loses its zinc and becomes red copper again.

Copper combines with mercury, but not readily; yet by triturating very thin leaves of copper with mercury, these metals may be formed into a sort of amalgam. A plate of this metal immersed into a solution of mercury by an acid, takes a fine silver colour, owing to the mercury being reduced and precipitated by the copper, which has a greater affinity than that semi-metal with oxygen.

Copper and lead combine very well by fusion; as appears by the formation of the loaves of eliquation.

It is combined with tin in two ways; either by pouring

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ing melted tin on the surface of a plate of copper, or by melting the two metals together. The former operation is used in tinning copper; the latter forms bronze. Copper vessels to be tinned are first well scoured, to render the surface on which the tin is to be applied smooth and bright. They are next rubbed with ammoniacal muriate, to make them perfectly clear. They are then made hot, and powdered rosin is cast upon them. This substance covers the surface of the copper so as to prevent it from being oxidated. At last the melted tin is poured on, and spread over it. Complaints have been made, and with good reason, that the tinning of copper-vessels is not sufficient to defend them from the action of air, of moisture, and of salts; because such vessels are often observed to be covered with verdigris. This might be effectually remedied by laying on a thicker coat of tin, were there not reason to fear that when such vessels are exposed to any degree of heat above that of boiling water, the tin is then liable to be melted, and thus to expose the surface of the copper uncovered. To prevent such an accident, the tin may be alloyed with iron, silver, or platina, to render it harder and less fusible, in order that it may be laid in thicker layers on the copper. Mixtures of this kind are already made use of in several manufactories. It is amazing how small a quantity of tin is sufficient to tin copper; for Messrs Bayen and Charlard have ascertained, that a pan nine inches in diameter and three lines in depth, gained only an additional weight of one and twenty grains by being tinned. This trifling quantity, however, is sufficient to prevent the danger which might otherwise arise from the use of copper-vessels, when care is taken not to suffer substances capable of dissolving tin to remain too long in such vessels, and e-

pecially to renew the tinning frequently, as friction, heat, and the action of the spoons used in stirring substances boiled in them, very soon destroy the tinning. There is one thing, however, respecting the tin used by copper-smiths for tinning pans which we cannot be too much on our guard against. It is often alloyed with one-fourth part of lead; the bad effects of which are to be feared, as it is well known in fats and acids. Government should therefore take measures to prevent copper-smiths from being cheated when they purchase their tin, and from employing the tin of Malacca or Banca in any other state but as it comes from the East-Indies, before being melted again, and having its purity debased by our tin-workers.

M. de la Folie, a citizen of Rouen, who merits the respect of the public for those chemical researches which he has prosecuted on matters relative to the arts, and for the useful discoveries with which he has enriched dyeing, pottery, and many other of the manufactures carried on at Rouen, has proposed, in order that the inconveniences and dangers attending the use of tinned copper may be avoided, to employ in its stead iron plated with zinc; which, as we have already seen, is productive of no dangerous effects. Many people have already adopted the use of such vessels with advantage; and it is to be wished that they were in general use.

Tin melted with copper gives a metal, the specific gravity of which is greater than that of either of the two metals of which it is made up, in consequence of their mutually penetrating each other in a very intimate manner. The greater the proportion of tin in this mixture, so much the more white, brittle, and sonorous is the mixture. When very white, it is called *bell-metal*:

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When it contains more than an equal proportion of copper, it is yellow, and bears the name of *bronze*, or *brass*. It is moulded into statues and into cannons, which must be so solid as not to burst by a moderate force; and at the same time not so ductile as to lose their form by the impulse of bullets.

Copper and iron may be united by fusion or by soldering. This combination, however, does not very easily succeed. When a mixture of these two metals is melted in a crucible, the iron is found to be intermixed, but not perfectly united with the copper. Copper decomposes the mother water of sulphate of iron; and yet iron has a greater affinity than acids with copper.

The uses to which copper is applied are very various and very well known. A great variety of utensils are made out of it. Yellow copper, or an alloy of copper with zinc, is principally employed for such purposes, on account of its superior ductility and beauty. Copper being a very violent poison, should never be administered as a medicine. The remedies most usually applied in the case of poisoning by copper reduced to oxide or verdigris, are emetics, water drunk in large quantities, alkaline sulphures, alkalis, &c.

CHAP. XX.

Of Silver.

SILVER, called *Luna*, or *Diana*, by the alchemists, is a perfect metal of a white colour and the most lively brilliancy. It has neither taste nor smell. Its specific gravity is such, that it loses in the hydrostatic balance about one-eleventh part of its weight. A cubic foot of this metal weighs seven hundred and twenty pounds. So great is the ductility of silver, that it may be reduced to leaves as thin as paper, and to threads finer than hairs. A grain of silver may be extended so as to contain an ounce of water. Its tenacity is so considerable, that a thread of silver, one-tenth of an inch in diameter, is sufficient to support the weight of two hundred and seventy pounds without breaking. It possesses hardness and elasticity in an inferior degree to that in which copper possesses these qualities; it is next after copper the most sonorous of all metals. It becomes hard under the hammer, but may be easily deprived by heating of the hardness which it thus acquires.

quires. Messrs Tillet and Mongez have crystallized silver. They obtained it in quadrilateral pyramids, sometimes solitary on the edges of the crucible, at other times laterally united in groups.

Silver is found in various states in nature. The following are the silver ores most strikingly distinguished from each other.

1. Native, or virgin silver. It is known by its lustre and ductility. It appears under an amazing variety of forms. It is frequently in irregular masses, the size of which is more or less considerable. It is sometimes in capillary threads twisted round; its formation then appears to be owing to the decomposition of a red silver ore, as has been observed by Henckel and M. Romé de Lille. It is likewise found in plates, or in pieces of net-work resembling spider's webs, which the Spaniards on this account call *arané*; sometimes again in a vegetable form, or in branches consisting of octohædrons rising one over another. Some of these specimens resemble the fern leaf, others are in separate cubes and octohædrons, with truncated angles; but these last are rare. Native silver is often dispersed in a quartzose gangue; it is sometimes found in fat earths. It is found in Peru, in Mexico, at Kongsberg in Norway, at Johan Georgenstadt and Ehrenfriedersdorf in Saxony, at St Marie, at Allemont in Dauphiny, &c. This metal is not known to exist in nature in the state of oxide.

2. Native silver, in union with gold, copper, iron, antimony, or with gold and copper together, or with arsenic and iron together. These various native combinations of silver are found at Freyberg in Saxony, and in the mines of Guadal-Canal in Spain. But it is

to be observed, that the proportion of the extraneous substances is very trifling:

3. *Vitreous silver ore* consists, according to most mineralogists, of silver and sulphur. It is of a blackish grey colour like lead; it is also brown, greenish, yellowish, &c. and it may be cut with the knife as well as that metal. It is frequently irregularly shaped, sometimes in octohædral crystals, the angles of which are truncated. M. Monnet takes notice of a variety, which, instead of being divisible by the knife, falls into powder. This ore affords from seventy-two to eighty-four pounds of silver in the hundred weight. It melts very easily: when exposed to a heat so moderate as not to melt it, the sulphur is dissipated, and leaves the virgin silver in a vegetative form, or in filaments.

4. *Red silver ore* is often of a deep colour, sometimes transparent, and crystallized in cubes with their edges truncated, or in hexahædral prisms terminating in trihædral pyramids: at Potosi this is called *rossi-clera*. The silver is combined in it with sulphur and arsenic. When it is broken, its colour is lighter within, and it appears to consist of small needles or prisms converging like stalactites. If exposed, with proper management, to a fire strong enough to make it red hot, the silver is reduced, and takes a capillary vegetative form like native silver. It affords from fifty-eight to sixty-two pounds of silver in the hundred weight. This species is diversified into varieties by the properties of colour, form, and gravity, &c. It is generally found in all such places as contain the other silver ores.

5. Silver with arsenic, cobalt, and iron mineralized by

by sulphur. Bergman says, that in this ore the silver is sometimes above the proportion of $\frac{1}{100}$. This ore is sometimes grey and sparkling, sometimes of a dark and dusky appearance; efflorescences of cobalt are observable upon it. The silver ore called *goose-dung* belongs to this species.

6. The grey silver ore; which differs from the copper ore called *Fahlertz* only in containing a larger proportion of this precious metal. It is either in masses or in triangular crystals, with their sides cut sloping. The largest of these crystals are not of a very bright colour; the small, being dispersed over a smooth gangue, are of so lively a lustre as to afford a very pleasing spectacle when light falls upon them. Grey silver affords from two to five marks of silver in the hundred weight. Grey silver is sometimes introduced into organic matters, and moulded into an exact imitation of their form. It is then called *figured silver ore*. Of this kind is that resembling blades of corn, and that which M. Romé de Lille has observed in the form of the cones and scales of the pine-tree. This ore contains silver, copper, iron, arsenic, and sulphur. When the proportion of the iron is very small, it is then called *white silver ore*. This latter ore is not to be confounded with galena containing silver, which is sometimes called by the workmen *silver ore*.

7. Black silver ore, called by the Spaniards *nigrillo*, is, according to Messrs Lehman and Romé de Lille, nothing but red or grey silver ore decomposed and brought into a kind of middle state between its original state and that of native silver: it is sometimes found to contain native silver. The latter of these two mineralogists has observed, that when solid, spongy, or worm-eaten, it may be considered as produced from the red and

vitreous ores, and is then richer than when friable and pitch-coloured; when it may be considered as originating from the alteration of grey or white silver ores. It therefore affords various products. In general, it affords from six or seven to nearly sixty pounds of silver in the hundred weight.

8. *Corneous silver ore*, or the natural combination of silver with muriatic acid, and a little sulphuric acid, is of a dirty yellowish grey colour: it sometimes inclines to a grizelin colour; sometimes, tho' but seldom, it is semi-transparent: it is soft, and may be easily crushed or cut: it melts at the flame of a taper. It is found in cubic crystals, but ofteneft in irregular masses. It frequently contains lumps of native silver. It was formerly thought to contain sulphur and arsenic; but mineralogists are now agreed in respect to its nature. Messrs Cronstedt, Lehman, and Sage, Woulfe, Lommer, and Bergman, have found it to contain muriatic acid, which is disengaged by heat. Woulfe has besides ascertained it to contain sulphuric acid. It is found at Saxony, at St Marie, at Guadal Canal in Spain, and at Allemont in Dauphiny.

9. *The soft silver ore* of Wallerius, is silver either native or mineralized, and intermixed with more or less coloured earth. Earths containing silver vary in colour from a dirty grey to a deep brown.

10. Lastly, Silver is often found in combination with other metallic matters in ores, the history of which we have already given. Such are mispickel, the grey cobalt ore, kupfernickel, or nickel ore, sulphure of antimony, which often affords the variety called *silver ore in feathers*, *blende*, *galena*, *martial pyrites*, and *white copper ores*: the latter are only grey silver ores. All of these substances, many times, contain so much silver, as

renders

renders the working them for the sake of this precious metal profitable. But it is easy to see, that they cannot, with any propriety, be described as peculiar silver ores; and deserve only to be mentioned as containing silver.

Silver ores are assayed in various ways, according to the nature of the ore. All that is strictly requisite in assaying such as contain native silver, is to pound and wash them. In order to separate the metal entirely from extraneous substances altering it, after being washed, it may be triturated with running mercury. The mercury dissolves the silver, and being then volatilized by fire, leaves the perfect metal separate. Sulphureous silver ores need to be roasted, and afterwards melted with a greater or a less quantity of flux. The silver obtained by this melting is commonly alloyed with lead, copper, iron, &c. To separate it, and to ascertain exactly what quantity of the precious metal this mixture contains, a process entirely chemical, and founded on the consideration of the properties of the imperfect metals, is employed. As lead is susceptible of vitrification, and acts in the quality of a flux on the imperfect metals, such as iron and copper, but is incapable of affecting silver in the same manner; lead is therefore employed to separate the perfect metal from such imperfect metals as alter it. The greater the proportion of the extraneous matters by which the silver is altered, so much the more lead must be made use of to separate them. This alloy is put into flat porous vessels, made of calcined bones and water. These roasting pots, which are called *cupels*, as being in the form of small cups, are proper for absorbing the lead-glass formed in this operation. The silver after this remains pure. In order to determine what quantity of
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the imperfect metals any mass of silver contains, it is considered as consisting of twelve parts, which are called *penny-weights*; and each of these consists of twenty-four grains. If the mass of silver under examination has lost in the cupels only a twelfth-part of its weight, it is called *silver of eleven penny-weights*: if it has lost but a twenty-fourth part of its weight, it is *silver eleven penny-weights and twelve grains fine*, and so on. The cupel is found, after this operation, to have acquired a considerable addition of weight: it contains vitreous oxide of lead, and of the other imperfect metals, which were in combination with the silver, and have been separated by the lead. As the lead almost always contains a little silver, it must be at first cupelled by itself, in order to ascertain what quantity of silver it contains: from the button of fine silver obtained, a deduction must be made for the small portion known to be contained in the lead which is employed, and is called a *witness*. The cupellation exhibits a phenomenon from which the artist understands the state of his operation. As the silver becomes pure by vitrification and the separation of the lead, it assumes a much more brilliant appearance than that with which the lead is still intermixed. The lustre by degrees increases; and when the whole surface of the metal becomes pure and of a dazzling brightness,—at the very instant when the whole assumes such an appearance, the operation is finished. The silver, after being thus cupelled, is entirely purified from the imperfect metals which it before contained: but it may still contain gold; and a new process must be employed to separate the two perfect metals. As gold is much less liable than silver to be altered by a great many menstrua, the silver is dissolved by the nitric or the muriatic acid and by sulphur; and the

the gold, which is scarce liable to be affected by these solvents, remains pure. This way of separating silver from gold is called *parting*. We will speak of the various ways of parting these metals, after describing in what manner the several solvents which are used for this purpose act upon the silver, and when we treat of the alloy of silver with gold.

The processes, in the great way, for extracting silver from its ores, and obtaining it pure, are nearly the same with those which we have described as proper for assaying the ores of this metal. There are, in general, three ways of treating silver in the great way. The first consists in triturating virgin silver with mercury: this amalgam is washed to purify it entirely from earth: it is then strained through goat-skin, and distilled in an iron retort; after which the silver is melted, and run into ingots. This process cannot be applied to silver ores containing sulphur. These must be roasted and mixed with lead, in order to refine the precious metal by cupellation. This is the process to which rich silver ores are subjected. As to such as are pure, the method employed upon them is different from either of these two. They are melted without being previously roasted with a certain quantity of pyrites. This is called *crude fusion*, and affords a mat of copper containing silver, which is treated with lead by eliquation. The lead which takes up the silver as it melts, is afterwards scorified in the cupel, and then leaves the perfect metal pure. Cupellation in the great way differs from that which is performed in the small way; for, whereas in the former the scorified lead is blown over the edges of the cupel with blow-pipes, in the assay the vitrified oxide of lead is absorbed by the cupel.

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The silver obtained by the processes which we have described is, in general, much less liable to alteration than any of the other metals of which we have given the history. The contact of light, however long the metal remain exposed to it, produces no change of its properties. Heat melts it, makes it boil, and volatilizes it, but without altering its nature. An heat sufficient to make it become first red, and afterwards white, is requisite to melt it: it is more fusible than copper. After being kept for some time in fusion, it swells and exhales vapours which are nothing but silver volatilized. What puts this fact beyond doubt is, that portions of the metal are found in the funnels of chimnies in which it is melted in large quantities. It is confirmed by a fine experiment of the Academicians of Paris; they exposed very pure silver to the focus of M. de Trudaine's lens, and observed the melted metal to diffuse a thick smoke, which being intercepted by a plate of gold, was fixed upon it, and whitened its surface.

Silver when slowly cooled, is susceptible of a regular form, and crystallizes in quadrangular pyramids. M. Baumé observed, that this metal takes, as it cools, a regular form; which appears from its surface being covered over with filaments resembling the threads of a feather. I have remarked, that the button of fine silver obtained by cupellation, often exhibits on its surface small spaces with five or six sides, arranged like the flags of a pavement. But its crystallization in tetrahedral pyramids has not been carefully examined by any but Messrs Tillet and the Abbé Mongez.

It was long imagined, and many chemists are still of opinion, that silver is secure against the joint action of
heat

heat and air. It is certain that this metal suffers no apparent alteration when held for some time in fusion, and in contact with air. Juncker, however, related, that on treating silver for a considerable time by reverberation, in the way of Isaac of Holland, he found it to change into a vitreous oxide. This fact has been confirmed by Macquer. He exposed silver twenty times successively in a porcelain crucible, to the heat of the porcelain furnace at Seves, and obtained, by the twentieth fusion, a vitreous matter, of an olive green colour, which he considered as a true vitreous oxide of silver. When this metal is heated in the focus of a burning-glass, its surface is always covered with a white pulverulent matter, and a greenish incrustation is formed on the body on which it rests. These facts remove every doubt that could be reasonably entertained of the alteration of silver in such circumstances. Tho' much more refractory against all attempts to reduce it to an oxide than any other metal; yet is it liable to be at length changed into a white oxide, which when treated in a very strong fire takes an olive green colour. It might perhaps be possible to obtain an oxide of silver, by reducing the metal to very thin plates or leaves, and heating it for a considerable time in a matrafs, in the same way as is done with mercury. The electric spark appears likewise to oxidate silver. It is certain, at least, that this metal has but a very faint tendency to combine with the base of vital air, and that heat does not contribute to this combination so much as in the case of any of the other metals; but on the other hand, destroys it by a very slight effort; for all the oxides of silver may be easily reduced without addition; and oxigene must therefore be but very imperfectly

fectly combined with the metal, since it can be detached from it so as to form vital air, by the action of light and heat alone.

Silver is liable to no alteration from air; its surface in a long space of time is a very little sullied by the action of the atmosphere. Water acts not upon it: earthy matters do not combine with this metal: Its oxide, if melted with glasses, would probably communicate to them an olive green colour.

Neither the alkalis nor the salino-terreous substances act in a sensible degree on silver. The sulphuric acid, when highly concentrated and boiling, and when the metal is presented in a state of extreme division, dissolves it. A considerable quantity of sulphureous acid gas is disengaged from this solution; and the silver is reduced to a white matter, on which a new quantity of sulphuric acid must be poured, in order to dissolve it. By evaporating this liquor, sulphate of silver is obtained in small needles. I have several times obtained this salt in plates, formed by the longitudinal junction of a number of these needles. This salt melts when exposed to fire, and is of a very fixed nature. It is decomposable by alkalis, iron, copper, zinc, mercury, &c. All the precipitates obtained by alkalis may be reduced without addition to fine silver, in close vessels.

The nitric acid oxidates and dissolves silver rapidly, even without the help of heat. This solution even takes place at times so quickly, that to prevent the inconveniences arising from this circumstance, it is found expedient to have the silver in lumps when exposed to the acid. A considerable quantity of nitrous gas is disengaged on the occasion, and a white precipitate is produced, more or less in quantity, if the acid of nitre have been mixed with any portion of sulphuric or muriatic acid. The

nitric

nitric acid usually gives it a blue or a green colour. If the silver be pure it loses that colour, and becomes transparent as soon as the solution is fully accomplished: but if the silver happen to contain copper, the solution retains a lighter or deeper greenish shade. The purest silver that can be obtained often contains gold. In that case, as the nitric acid is scarce capable of acting on that metal, when it acts on the silver it separates small blackish flakes, which fall to the bottom of the vessel, and prove to be gold. It is in consequence of the nitric acid acting in so different a manner on these two metals, that it is happily employed to separate them in the operation of parting by aquafortis. The nitric acid dissolves a quantity of silver equal to half its own weight. This solution is exceedingly caustic; so much so, that it produces black spots on the epidermis, and eats entirely through it. When strongly concentrated, it deposits thin bright crystals like the boracic acid: when half the quantity is evaporated, it affords, by cooling, flat crystals, which are either hexagonal, or triangular, or square, and appear to consist of a great many small needles joined laterally. These flat crystals are obliquely arranged one over another. They are transparent and very caustic. They are called *Lunar crystals*: their proper name is nitrate of silver. This salt is speedily altered by the contact of light, and rendered black by combustible vapours. When placed on a burning coal it readily detonizes, leaving after the detonation a white powder, which consists of pure silver: it is very fusible. If exposed to fire in a crucible, it swells at first as it loses the water of its crystallization; and after that remains in fusion without motion. If suffered to cool in this state, it becomes a grey mass, slightly needled; a preparation which is known in surgery

gery under the name of the *infernal stone*. But there is no occasion to make use of crytallized nitrate of silver when we wish to obtain this medicine; the process by which it is made up is too tedious and too expensive. It is sufficient to evaporate to dryness a solution of silver by the nitric acid, to put the residue in a silver crucible or ladle, as M. Baumé advises, and to heat it slowly till it melt; it may be then run into a mould to give it the form of small cylinders. When these cylinders are broken, they appear to consist of needles diverging in radii from the centre of the cylinder, and terminating at its circumference. In composing the *infernal stone* of nitrate of silver, we must beware of heating it too long; otherwise a part of the salt will be decomposed and formed into a button at the bottom of the crucible. In order to have an opportunity of observing what passes in this operation, I distilled this salt in a pneumato-chemical apparatus; I obtained nitrous gas and vital air, mixed with azotic gas. In my matrass I found the silver entirely reduced; the glass was become opaque, like enamel, and was of a beautiful chestnut-brown colour. The brown colour which the glass takes on this occasion must, no doubt, be owing to oxide of manganese, or some other substance contained in it; for the colour of glass formed of oxide of silver is nearly an olive green, as we have already observed.

Nitrate of silver does not attract moisture when exposed to the air; it dissolves very readily in water, and may be crytallized from the solution by a slow evaporation of the fluid.

The nitric solution of silver is decomposed by saliniferous terreous substances and alkalis; but the phenomena vary greatly, according to the state of the matters. Lime-

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water produces a very copious olive-coloured precipitate. Fixed alkali, saturated with carbonic acid, makes it yield a white precipitate: caustic ammoniac causes it to afford a grey precipitate, inclining to olive green. This precipitation does not take place till a considerable time after the two substances have been mixed.

Although the nitric acid act with a stronger energy on silver than any of the other acids, there are, however, others which have a greater affinity with its oxide, and adhere to it with more obstinacy: the sulphuric and the muriatic acids detach the oxide from the nitric acid. For this reason, when a few drops of either of these acids are poured into a nitric solution of silver, a precipitate is produced; which, when the sulphuric acid is employed, is a white powder; and when it owes its origin to the muriatic acid, in thick flakes like a *coagulum*. In the former case the precipitate is sulphate of silver; in the latter, muriate of silver. As neither of these two salts is very liable to solution, they therefore subside in a precipitate. It is not necessary that the acids be in a state of liberty when applied to this purpose; the neutral salts which are formed by their combinations with alkalis and salino-terreous substances serve the purpose equally well. A double decomposition and a double combination then take place; for the nitric acid, separated from the silver, enters into combination with the base of the sulphuric or muriatic salt.

On this difference among the acids, in respect to the manner in which they act upon silver, there is founded a process which is employed to procure the nitric acid in an high state of purity, and unmixed with any other acid: in a word, in that state in which it is requisite to have it for many operations in metallurgy, and for most

chemical experiments. Distilled spirit of nitre is generally mixed with a certain quantity of sulphuric or muriatic acid; and chemists have therefore industriously sought to separate these extraneous fluids, and have found no happier expedient than the use of the nitric solution of silver. This solution is poured into the impure nitric acid till it cease to produce a precipitate; the sediment of sulphate or muriate of silver is suffered to settle; the acid is decanted off, and distilled by a moderate heat to separate from it that small quantity of salts of silver which may still be contained in it. The product of this distillation is very pure nitric acid: in the arts it is called precipitated aquafortis.

Most metallic matters are capable of decomposing the nitric solution of silver, as they have in general a greater affinity than that metal with the nitric acid. Arseniate of potash, dissolved in water, produces in the nitric solution a reddish precipitate, which originates from the union of the silver with the arsenic. This precipitate resembles red silver ore. The silver may be obtained in its metallic state, as a precipitate from this solution by most of the metals and the semi-metals. But the separation of this perfect metal by mercury and copper is particularly worthy of our notice, on account of the phenomena which attend the first of these metallic substances as it acts on silver, and the useful purposes which are served by bringing the second to act upon it.

Silver, when separated from the nitric acid by mercury, is in a metallic state; and the precipitate subsiding slowly, produces, as it subsides, a regular figure known by the name of *Diana's tree*, or *the philosopher's tree*. This species of crystallization may be obtained by several different processes. Lemery directed to take

an ounce of fine silver, to dissolve it in nitric acid moderately strong, and to dilute the solution with about twenty ounces of distilled water, adding two ounces of mercury. In the space of 40 days a very beautiful vegetative form is produced. Homberg gives another process much shorter than this. His process is, to make a cold amalgam of four drachms of silver in leaves with two drachms of mercury: this amalgam is to be dissolved in a sufficient quantity of nitric acid, and a pound and an half of distilled water to be added to the solution: into an ounce of this liquor put a small ball of a soft amalgam of silver, and the precipitation of the silver will immediately take place. The silver being precipitated and combined with a part of the mercury, is deposited in a kind of prismatic filaments on the surface of the amalgam. Other filaments rise above the first, till we behold the form of a vegetable bush. Lastly, M. Baumé has described a way of obtaining the tree of Diana, a little different from Homberg's process, and more infallibly attended with success. He directs to mix six drachms of the solution of silver and four drachms of a solution of mercury by the nitric acid, both fully saturated; to add to the mixture five ounces of distilled water; and then to pour it into an earthen vessel upon six drachms of an amalgam made up of seven parts of mercury with one of silver. Either of these processes succeeds in a much shorter time than Lemery's, in consequence of the relation subsisting between the metallic matters and their mutual action. In fact, the mercury contained in the solution attracts the mercury of the amalgam; the silver of the amalgam acts in the same way on the silver of the solution: and, of consequence, the silver is more speedily precipitated. The mercury of the amalgam, being more than what is requisite to precipitate

pitate the silver of the solution, produces a third effect, which we must not suffer to escape unnoticed: It attracts the silver by its affinity and tendency to combine with that metal: a combination is actually effected between them; for the vegetation of the tree of Diana is a real amalgam, brittle and crystallized. This crystallization succeeds much better in conical vessels, such as glasses, than in round or wide vessels like the cucurbite recommended by M. Baumé. It is almost unnecessary to mention, that the vessel must not be moved, nor exposed to any impulse which might hinder the regular symmetrical arrangement of the amalgam.

Copper immersed into a solution of silver likewise precipitates it in a bright metallic form. This is the process usually employed to separate silver from its solvent, after the operation of parting. Plates of copper are dipped into the solution, or rather the solution is put into a copper vessel; the silver is immediately separated in whitish grey flakes. When the liquor becomes blue, and ceases to precipitate silver, it is decanted off. The silver precipitated is repeatedly washed, then melted in crucibles, and passed with lead into a cupel, to separate from it a portion of copper which became united with it in the precipitation. The silver which passes through this operation is purer than any other kind: it is no less than twelve penny-weights fine. From these two cases of the precipitation of silver by mercury and by copper, it appears that metals separated from their solvents by metallic matters, are precipitated with all their properties. This phenomenon, as we have shown in the history of copper, takes place in consequence of the metals immersed into the solution of silver, robbing it of its oxigene, with which they have a greater affinity.

The

The muriatic acid does not dissolve silver immediately; but it dissolves its oxide readily enough. This acid supersaturated with oxygen easily oxidates the metal. Such, no doubt, is the reason of what happens in the *concentrated parting*. This operation consists in exposing to fire plates of gold alloyed with silver, cemented with a mixture of sulphate of iron and muriate of soda: The sulphuric acid disengaging the muriatic, communicates to it a portion of its own oxygen; and the muriatic acid then acts upon the silver, and dissolves it.

There is a much easier and more expeditious process for combining the muriatic acid with oxide of silver. The acid is poured into a nitric solution of the metal: a very copious precipitate is instantaneously formed, and proves to be a combination of the muriatic acid with silver; for the metal has a greater affinity with the muriatic than with the nitric acid, and of consequence forsakes the latter to combine with the former. The same combination may be obtained by pouring muriatic acid into a solution of sulphate of silver; for this acid has likewise a greater affinity than the sulphuric with the metal. The muriatic acid may also be combined with silver, by heating the acid with oxide of the metal precipitated from the nitric acid by fixed alkali.

Muriate of silver possesses various properties worthy of notice. It is remarkably fusible. When exposed in a phial to a moderate heat, such as that of hot ashes, it melts into a grey semi-transparent substance, bearing no small resemblance to horn; and for this reason called *corneous luna*. If run upon a surface of porphyry, it fixes into a friable matter, appearing to be crystallized in fine silver needles. When long heated in contact with air, it is decomposed; it passes easily thro' the crucibles; one part of it is volatilized, and another

reduced to metal; so that it now takes the form of silver globules dispersed through muriate of silver; a portion of the salt remaining not decomposed. This salt, when exposed to light, loses its whiteness, and becomes speedily brown. It dissolves in water; but, according to an experiment of M. Monnet's, a pound of distilled water dissolves only three or four grains. Alkalis are capable of decomposing muriate of silver, when it is either dissolved in water or exposed to fire together with any of these salts. This is one way of obtaining the finest and purest silver possible. Mix, for this purpose, four parts of potash, or carbonate of potash, with one of muriate of silver; Put the mixture into a crucible and melt it; when it is completely melted, take it out of the fire; suffer it to cool, and then break it: separate the silver; which is found under the muriate of potash formed during this operation and the excess of alkali. M. Baumé, to whom we owe this process, asserts, that the quantity of alkali which he directs to be employed hinders the muriate of silver from passing through the crucible, by acting on all its parts, and decomposing them at once. Margraff has given another process for reducing this salt, and obtaining from it silver perfectly pure. Triturate in a mortar five drachms and sixteen grains of muriate of silver with an ounce and an half of ammoniacal carbonate; add as much distilled water as may be sufficient for making it into a paste: stir this mixture till the swelling and effervescence which at first take place in it cease: then add three ounces of pure mercury, and triturate the whole till it be formed into a beautiful amalgam of silver: wash it with a good quantity of water; continue the trituration, and repeat the washing till the water run off very clear, and the amalgam become very bright: then dry the

amalgam, and distil it in a retort till the vessel take a white red colour: the mercury now passes into the receiver, and the silver is found in an high state of the retort. In this manner the metal may be obtained of the highest purity possible, and without any sensible loss. This sort of silver should be used in nice chemical experiments. The water employed to wash this mixture carries off two substances; a certain quantity of ammoniacal muriate, which it holds in solution, and a white powder not soluble in water. When the white powder is sublimated, there is a small quantity of silver found at the bottom of the sublimatory vessel. This experiment proves, that muriate of silver cannot be completely decomposed otherwise than by double affinity. In fact, in Margraff's process, the cause of the ammoniac combining with the muriatic acid is, that the silver is first detached from the acid by the mercury, and the alkali then becomes capable of effecting an event which it could not otherwise have produced. But this tedious and expensive operation can only be employed in the small way and in the laboratory. To reduce a great quantity of muriate of silver at once, either fixed alkali, or some metallic substance having a greater affinity than silver with the muriatic acid, must be employed. Such, among others, are antimony, lead, tin, iron, &c. One part of muriate of silver melted in a crucible with three parts of any of these matters, affords, at the bottom of the crucible, the silver reduced and separate; while the metal employed to produce the separation appears in union with the muriatic acid. The silver precipitated in this manner is very impure; it always contains more or less of the metal employed to separate it: and as, in compliance with the advice of Kunckel, lead is most commonly employed for the purpose, this

silver needs to be cupelled ; nor can it even be rendered equally pure with that which is reduced by alkalis, or by Margraff's process.

The nitro-muriatic acid acts with considerable force on silver ; and as it dissolves it, causes it to precipitate. The manner in which this effect takes place may be easily understood : the nitric acid dissolves the metal at the first, and the muriatic acid detaching itself from the nitric forms a neutral salt with the silver ; which, having no great tendency to solution, is deposited in sediment. This process may be used to separate silver from gold.

We know but little about the manner in which the other acids act upon silver ; only, a solution of borax produces in the nitric solution of this metal a very copious white precipitate ; which precipitate consists of boracic acid in union with oxide of silver.

This metal does not appear liable to be altered by neutral salts. It is certain, at least, that it does not detonize with nitre, nor decompose ammoniacal muriate. Silver, in consequence of its being unalterable by nitre, may be easily separated from imperfect metals, such as copper, lead, &c. by detonizing them with that salt. This metal, alloyed above the just proportion with some of the baser metals, is melted with nitre : the salt detonizing burns the imperfect metal ; and the silver falls to the bottom of the crucible in a state of much higher purity.

Almost all combustible matters act with more or less force on silver. No metal is sooner tarnished or coloured by inflammable matters. Sulphurated hydrogenous gas, from whatever substance disengaged, communicates to silver the instant it comes into contact with it a blue or violet colour, inclining to black, and considerably dis-

minishes

minishes its ductility. It is known that foetid animal vapours, such as proceed from houses of office, from putrefied urine, and from hot eggs, produce the same effect on this metal. The mutual action of these bodies, and the combination which takes place on the occasion, have not yet been examined.

Sulphur combines very readily with silver. This combination is usually effected by stratifying on a crucible plates of the metal with flowers of sulphur, and melting the mixture hastily: the result is a violet black mass, much more fusible than silver, brittle, and needled: in a word, a true artificial ore. This composition is easily decomposed by the action of fire, on account of the volatility of sulphur and the fixity of silver: the sulphur is consumed and dissipated, leaving the silver pure. Alkaline sulphure dissolves this metal in the dry way: on melting one part of silver with three of sulphure of potash, the metal disappears, and may be dissolved in water together with the sulphure. An acid poured into the solution produces a black precipitate of sulphurated silver. Leaves of silver put into a solution of sulphure of potash speedily take a black colour; and it appears that the sulphur forsakes the alkali to unite with the metal and mineralize it; as we have already observed of mercury,

Arsenic combines with silver and renders it brittle. We know not yet how the acid of arsenic affects this metal.

It combines, but not without great difficulty, with cobalt.

It enters readily enough into an alloy with bismuth, forming with it a brittle mixed metal, the specific gravity of which is greater than that of either of the two metals taken separately. According to Cronstedt, silver

ver does not unite with nickel. These metals, when melted together, are disposed separately, one beside the other, as if their specific gravities were precisely equal.

It melts with antimony into a very brittle alloy. It appears to be capable of decomposing sulphure of antimony, by combining with the sulphur of that mineral, with which it has a greater affinity than antimony has.

Silver easily combines with zinc by fusion. From this combination there results an alloy granulated at the surface, and very brittle.

In mercury, even cold, it is completely dissolved. All that is necessary to effect this solution, is to malaxate leaves of silver with this metallic fluid: an amalgam is by this means instantaneously produced; the consistency of which varies with the respective quantities of the two substances. This amalgam may be brought into a regular form by fusion and slow evaporation: it affords tetrahedral prismatic crystals terminating in pyramids of the same form. The mercury becomes in some degree fixed in this combination: for, to separate it from the silver, a stronger heat is required than what is sufficient to volatilize it when taken by itself. Silver decomposes corrosive mercurial muriate either in the dry or in the humid way.

It unites perfectly with tin; but entirely loses its ductility when alloyed with ever so small a proportion of that metal.

It enters readily into union with lead, which renders it very fusible, and destroys its elasticity and sonorousness.

It forms an alloy with iron, which might be very advantageously employed in the arts.

Lastly, it melts and combines in any proportion with copper. Copper does not destroy its ductility; but renders

renders it harder and more sonorous ; and the alloy is often employed in the arts.

Silver, on account of its ductility, and its being proof against the attacks of fire and air, is a metal singularly useful. Its lustre recommends it for an ornament : it is laid on the surfaces of various bodies, and even of copper : it is wrought into stuffs, and adds considerably to their beauty. But the most important use for which it serves, is that of a good material out of which vessels of all kinds may be made ; and its hardness and ductility render it peculiarly suitable for this purpose. The silver wrought into plate is commonly alloyed with $\frac{1}{4}$ of copper, which improves its hardness and cohesion, without rendering it in any degree dangerous to the health of those who use it ; for twenty-three parts of silver are sufficient to destroy all the noxious qualities of one part of copper.

Lastly, silver is coined into money, and used as a sign of value for all sorts of commodities ; but in this case it is alloyed with $\frac{1}{12}$ of copper, and is, of consequence, only eleven pennyweights fine.

C H A P.

C H A P. XXI.

Of Gold.

GOLD, the sun of the alchemists, is of all known metals the most perfect, and the least liable to alteration: its colour is a bright yellow. It is next after platina the most ponderous body in nature: in water it loses only between a nineteenth and a twentieth part of its weight: neither its hardness nor its elasticity is very considerable. Its ductility, of which gilding and gold wire afford such amazing proofs, is so great, that an ounce of gold is sufficient to give a silver thread four hundred and forty-four leagues in length; and it is reducible into leaves that may be carried about before the wind. It is calculated by Lewis, that a grain of gold will cover an area more than four hundred inches square. It is the most tenacious of all metals; for a thread of gold one-tenth of an inch in diameter, is sufficient to support five hundred pounds weight without breaking. Gold soon becomes hard and brittle under the hammer; but heat restores its ductility.

The

The colour of gold is subject to a good many varieties. It is sometimes more or less yellow or pale, and sometimes almost white: these differences, however, appear to be owing to some mixture. Gold has neither taste nor smell: It crystallizes by cooling into short quadrangular pyramids. Messrs Tillet and Mongez obtained it in this form.

Gold is found in nature almost in a pure and virgin state. It is sometimes met with in small masses, either solitary or continuous, and in a bed of quartz: At other times it is in small spangles, among sand under water: Lastly, It is extracted from various ores, into the composition of which it enters; such as galena, blende, red silver ore, and virgin silver. It is almost always united with a certain quantity of silver, or some other metal, forming thus a natural alloy.

There are several varieties of native gold. It exists in plates, in grains, in crystals; which are either octahedral, in prisms of four faces, or striated in filaments, and in irregular masses. M. Sage thinks, that native gold in prisms is combined with a certain quantity of mercury, which renders it brittle.

Modern mineralogists reckon up various species of gold.

1. Native gold in union with silver, copper, iron, &c. It is found in Peru, Mexico, Hungary, Transylvania, &c.

2. Auriferous pyrites: It is not easily distinguished from other pyrites by the eye: we discover the gold by dissolving it in the nitric acid, and washing the residue. Gold is only mixed, not combined, in martial pyrites. Some arsenical pyrites, particularly those of Saltzbergh in Tyrol, contain likewise a little gold.

3. Gold mixed with silver, lead, and iron mineralized

by sulphur. This auriferous ore is of a very mixed nature. According to M. Sage, it is found to contain blende, galena, specular antimony, copper, silver, and iron; the gold melts and drops out with the lead when the mass is exposed to heat. It comes from Naggyac in Transilvania.

Gold ore is assayed in different ways, according to its nature; pulverization and washing are sufficient with native gold. Gold alloyed with other metals must be roasted, melted, and cupelled with lead, and parted.

It is very easy to conceive in what way gold is extracted from its ores, after what has been already said on metallurgy in this work. Native gold needs only to be separated from its gangue. For this purpose, it is first pounded; then washed, to separate the powder of the gangue; then triturated in a mortar full of water, with 10 or 12 parts of mercury; the water being poured off after this operation, washes away every earthy particle from the metallic substance. When the amalgam thus formed appears to be sufficiently purified from earth, it is strained through goat skins. Great part of the mercury passes through; a certain quantity remains still united with the gold. The amalgam is next heated, and the mercury separated from it by distillation; the pure gold obtained by this distillation is then melted, and run into bars or ingots. With respect to the gold that is found in combination in the ores of other metals, such as lead, copper, silver; it is extracted by eliquation, cupellation, and parting. The lead which runs down from the eliquation of copper carries with it the silver and the gold. It is then cupelled, to separate the lead; and the silver, as we shall hereafter mention, is separated by parting.

Gold

Gold exposed to fire, becomes red hot before it melts. When very red, it assumes a dazzling lustre, and a clear green colour, like that of the aqua-marina. It does not melt till its colour change to a white red; when cooled slowly it crystallizes. It suffers no alteration, however long it be exposed to fire, and however intense the heat; for Kunckel and Boyle found gold to have undergone no alteration by being exposed for several months to the fire of a glass-house. This inalterability of nature is only relative however to the degrees of heat which we are capable of applying to it by the use of combustible matters; for it appears that a much more intense and active heat, such as that of glass lenses, destroys the metallic properties of gold. Homberg observed, on exposing this metal to the focus of a lens of Tschirnhausen's, that it smoked, became volatile, and was even vitrified. Macquer observed, on exposing gold to the focus of M. Trudaine's lens, that it melted and exhaled a smoke which gilded silver, and could therefore be nothing but gold volatilized; that the globule of melted gold was agitated by a rapid internal motion, and became covered with a rough pellicle, shrivelled, and seemingly earthy; and that a violet coloured vitrification was at length formed in the middle of the gold. The vitrified part was by degrees enlarged, till it formed a kind of cap of a larger curvature than the globule of gold, and closely fixed on the gold, in the same manner as the transparent cornea appears fixed on the sclerotica of the eye. The extent of the glass became gradually larger, and the gold was diminished. The surface on which it rests is always coloured with a purple tinge, which seems to be owing to the glass which it has absorbed.

Time did not allow Macquer to vitrify a given quantity

tity of gold completely. He observed that it would be necessary to reduce the violet glass with combustible matters, in order to know whether it would afford gold, and whether it were oxide of that perfect metal. At any rate, we are of opinion, that vitrified gold may be considered as a true oxide of gold; and we are the rather induced to adopt this opinion, because in a number of operations, which we will immediately proceed to describe, it invariably takes a purple colour, and several preparations of it are used for colouring enamel and porcelain. Gold then, like other metallic matters, may be reduced to calx; only, like silver, it requires a more intense heat and longer time to make it combine with the base of vital air than any other metallic matter: these circumstances no doubt bear a near relation to its extraordinary density, and its faint tendency or aversion to combine with oxigene. It is reduced to a purplish oxide by electrifying it violently.

Gold suffers no alteration from the action of air. Its surface is only tarnished by the extraneous bodies which are continually floating in the atmosphere. Water does not alter it in any way; from the experiments of Garaye, however, it appears that this substance gradually divides it in the same manner as iron.

Gold in its metallic state does not combine with earths or salino-terreous substances. Its oxide enters into the composition of glasses, and communicates to them a violet or purple colour.

Gold is not liable to suffer from the attacks of the sulphuric acid, however highly concentrated, and even assisted by heat.

The nitric acid dissolves a few particles of this metal;

al; but it is perhaps rather mechanically than by a true combination. Brandt was among the first chemists who asserted gold to be soluble in the nitric acid: the fact has been since confirmed by the experiments of Scheffer and Bergman. But we must observe, that according to experiments made by the whole chemists of the Academy of Paris, the nitric acid produces this effect only in certain circumstances, which those philosophers have not particularly mentioned. M. Deyeux, member of the College of Pharmacy, has remarked, that the acid of nitre dissolves gold only when it is rudely, and contains nitrous gas. According to him, the acid is not pure in this state: he calls it *acid impregnated with gas*, and describes it as a kind of *aqua-regia*. We have elsewhere shown in what consists the difference between the nitrous and the nitric acid.

The muriatic acid alone, and in a state of purity, acts not upon gold in any sensible degree. Scheele and Bergman have discovered, that the oxygenated muriatic acid dissolves gold in the same way as *aqua-regia*; and forms also with the metal the same salt which it forms with the mixed acid usually employed to dissolve it. It is the excess of oxigene united with the muriatic acid which causes the solution to take place: it is accompanied with no sensible effervescence, like the other solutions of metals, by the oxygenated muriatic acid.

Aqua-regia has been considered as the true solvent of gold. It dissolves it, however, no better than the oxygenated muriatic acid. As it would be improper to repeat here what we have elsewhere said concerning the nature and properties of this mixed acid, and the varieties to which it is liable, according as the proportions of the two acids by the combination of which it is formed vary, we shall speak only of the man-

ner in which it acts upon gold. As soon as the nitro-muriatic acid comes into contact with this metal, it attacks it with an effervescence; which the more concentrated the acid the hotter the temperature, and the more divided the integrant parts of the gold, is so much the more lively. This operation may be more speedily effected by a moderate heat; at least a moderate heat is favourable in the beginning of the process. Bubbles then rise in constant succession till a part of the metal be dissolved. This action by degrees ceases; stirring or heat is requisite to make it continue. Nitrous gas is disengaged while the solution is taking place. The nitro-muriatic acid, when saturated with the full quantity of gold which it is capable of dissolving, takes a yellow colour of a lighter or a deeper shade. It is considerably caustic; it tinges animal matters with a deep purple colour, and corrodes them. When evaporated with proper management, it affords crystals of a beautiful golden colour resembling topazes, and appearing to be truncated octahædrons, and sometimes tetrahædral prisms. It is difficult enough to obtain this crystallization. M. Monnet thinks it owing to a neutral salt ready formed in the nitro-muriatic acid; and asserts, that in order to obtain it, the *aqua-regia* made use of should be composed of nitric acid with ammoniacal muriate, or muriate of soda. A mixed acid prepared in this manner cannot but contain nitrate of soda or ammoniacal nitrate. It is either the one or the other of these neutral salts, according to the chemist whose opinion we are mentioning, which occasions the crystallization of gold. It appears, however, that a solution of gold in nitro-muriatic acid made up of pure acids, is capable of affording crystals; and Bergman considers the salt as mu-

These crystals when heated melt and take a red colour. This salt powerfully attracts the moisture of the atmosphere. A solution of gold gives, by distillation, a beautiful red colour, which is nothing but muriatic acid impregnated with a little gold. The alchemists who have laboured so much upon gold, called this liquor *red lion*. A few golden crystals are likewise sublimated, the colour of which is a reddish yellow. Most part of the metal remains at the bottom of the crucible; and fusion purifies it so that it again displays all its properties.

The solution of gold may be decomposed by a great many intermedia. Lime and magnesia precipitate the gold in the form of a yellowish powder. Fixed alkalis afford the same phenomenon. But it is to be observed, that the precipitate is but very slowly formed; and the solution takes a reddish colour, if more alkali be employed than what is absolutely requisite, for the excess of alkali again dissolves the precipitated gold. The precipitate gold may be reduced by heat in close vessels; it is an oxide, and readily gives out its oxigene into the state of vital air. This oxide, however, is fusible with vitreous matters, and communicates to them a purple colour; for enamels and porcelain are coloured with a precipitate of gold, formed by mixing a solution of gold with liquor of flints.

Gold precipitated by fixed alkali exhibits likewise another property, very different from those which gold possesses in its metallic state: it is soluble in pure sulphuric, nitric, or muriatic acid. All of these acids, when heated on the yellowish precipitate of gold, readily dissolve it; but they do not take up so much of it as to afford crystals. When these solutions are evaporated, the gold is very quickly precipitated; the same thing happens by rest. M. Monnet has observed

a fact concerning the precipitation of gold by nut-gall *, which must not be forgotten ; it is, that the precipitate which is reddish, dissolves very well in the nitric acid, and communicates to it a beautiful blue colour.

Ammoniac precipitates the solution of gold in much greater abundance. This precipitate is of a brown yellow, and sometimes of an orange colour : when exposed even to a moderate heat, it detonizes with a considerable noise ; it has been called *fulminating gold*. Ammoniac is indispensibly necessary to its production. It may be formed, either by precipitating by fixed alkali a solution of gold made in nitro-muriatic acid, composed

* As we have taken notice only of the precipitation of iron by nut-gall, we shall give a short account of the phenomena which this astringent substance exhibit with most other metallic substances.

Nut-gall, with the solution of cobalt, gives a clear blue precipitate ; with the solution of zinc, an ash-green precipitate ; with the solution of copper, a green precipitate, which becomes grey and reddish ; with a solution of silver, it gives first reddish striae, which take afterwards the colour of burnt coffee ; with the solution of gold, a purple precipitate. These facts have been observed and described by M. Monnet, and he has observed farther, that these precipitates are soluble in acids, and that alkalis combine with the latter solutions without producing precipitates.

The academicians of Dijon have added to these facts the following new observations. 1. The solution of arsenic is not altered by nut-gall ; with the solution of bismuth nut-gall produces a greenish precipitate ; with the solution of nickel, a white precipitate ; with the solution of antimony, a bluish grey precipitate ; with lead, a stony sediment, the surface of which is covered with pellicles of a mixed green and red colour ; lastly, the solution of tin takes a dirty grey colour, by mixture with nut-gall, and gives a copious precipitate, somewhat of a mucilaginous nature. Under the article of the Gallic Acid, or acid of galls, in the vegetable kingdoms, several of these facts will again draw our attention.

ed with ammoniacal muriate; or rather, by precipitating by ammoniac a solution of gold made in aqua-regia, composed of pure nitric and muriatic acid. The fulminating gold thus obtained is always one-fourth more in quantity than the gold dissolved in the aqua-regia. There are some precautions necessary to be taken in order to escape suffering from the terrible effects of fulminating gold. In the first place, it must be dried cautiously and in the open air, at a distance from any fire; for a very moderate degree of heat is sufficient to make it fulminate. As friction alone would be enough to make it give an explosion, the vessels into which it is put must be stopped only with cork. Some unlucky accidents have shown, that crystal stoppers, by their friction on the necks of the bottles, may cause such particles of the powder as adhere to that part of the bottle to fulminate; and by communication with the rest of the powder, to produce the most dangerous effects. A terrible accident happened in M. Baumé's laboratory, of which he has given an account in his *Theory and Practice of Chemistry*.

Chemists have entertained various opinions concerning the cause of the detonation of fulminating gold. Baumé gave it as his opinion, that in this instance there was formed *nitrous sulphur*, which he considered as the fulminating principle of the compound. But Bergman has proved his theory inadmissible, having formed fulminating gold without nitric acid, by dissolving a precipitate of gold in sulphuric acid, and precipitating it anew by ammoniac. Neither can the fulmination of this gold be owing to ammoniacal nitrate; for after being copiously washed in water, which would certainly carry off any portion of that salt which it might contain,

tain, it still retained its fulminating powers. On examining attentively what passes in the detonation of fulminating gold, it is observed to take fire at the very instant when it shivers into pieces. When it is exposed to the moderate heat of warm ashes, it gives out, before the explosion, sparks like those of electric fire: when exposed to the spark produced by the Leyden bottle, it detonizes; a simple spark without motion does not kindle it: lastly, after fulminating, it leaves the gold in a metallic state. It appears, therefore, that the fulmination of this gold is owing to some combustible matter contained in the compound: And as ammoniacal gas is necessary to the production of fulminating gold, it is at present agreed, that the explosion ought to be attributed to that substance. This theory is founded on the following facts.

1. M. Berthollet has obtained ammoniac gas by applying a gentle heat to copper tubes containing fulminating gold, and communicating at one end by means of a syphon, with a pneumato-chemical apparatus with mercury. The gold was now no longer fulminating, but was reduced to oxide.

2. Bergman exposing fulminating gold to a degree of heat not sufficient to make it fulminate, gradually deprived it of its fulminating powers, by volatilizing the ammoniac gas which it contained.

3. When a few grains of fulminating gold are made to detonize in copper tubes communicating with a pneumato-chemical apparatus with mercury, azotic gas, and a few drops of water, are obtained as products, and the gold is found to be reduced. M. Berthollet, to whom we owe this fact, thinks that in this instance ammoniac is decomposed; that the hydrogen which it contains uniting with the oxigene of the oxide of gold, reduces it.

it by forming water; and that the azotic gas being thus set at liberty is consequently disengaged: the fulmination appears therefore to be owing to the combustion of hydrogen and the sudden disengagement of azotic gas.

4. The concentrated sulphuric acid, melted sulphur, fat oils, and æther, deprives this precipitate of its fulminating powers, by detaching its ammoniac.

A singular property of fulminating gold, which shows with what force it acts, is its making a mark or hole on any metal plate, such as a plate of lead, tin, and even silver, on which it is fulminated. But it does not appear to be liable to take fire in a very close vessel; for Lewis relates, that it produced no explosion when inclosed in an iron ball, and exposed to an intense heat. The cause of this phenomenon seems to be, that there is not then room for the disengagement of the azotic gas. Bergman, who did not well know the nature of the gas disengaged during the fulmination of this precipitate, and considered it as pure air impregnated with a little ammoniac, has given a similar explanation of the experiments made on this matter before the Royal Society of London. The reader may consult his valuable Dissertation *de calce auri fulminante*, in his *Opuscula*. M. Berthollet discovered that oxide of silver, precipitated from nitric acid by lime, and digested with ammoniac till it take a black colour, acquires the property of detonizing not only by a heat a very little superior to that of boiling water, but likewise by a slight friction against any body. Here, then, we have fulminating silver of a still more singular nature than the gold so called; which, however, owes its fulminating properties to the same cause. The ammoniac decanted

from above this oxide, deposites, by slow evaporation, small, bright, lamellated crystals, possessing the property of fulminating, even under water, by simple friction.

The solution of gold is precipitated by alkaline sulphures. When the fixed alkali combines with the acid, the sulphur that is precipitated unites with the gold; but this combination is not very permanent; it is enough to heat the gold, and the sulphur is then volatilized, and the perfect metal left in a state of purity. It is proper to observe, that the gold precipitated from a solution by an intermedium, is perfectly pure, even more so than gold obtained by parting, being separated from the silver which it would otherwise have contained, in consequence of that metal being precipitated into a muriate, even during the solution of the gold, as we have above observed.

Gold has not a greater affinity than all the other metals with the nitro-muriatic acid; on the contrary, almost any other metallic substance is capable of separating it from its solvent. Bismuth, zinc, and mercury, precipitate gold. A plate of tin immersed into a solution of gold separates this perfect metal into a powder of a deep violet colour, which is called purple precipitate of *Cassius*. This precipitate, which is used for painting on enamels and porcelain, is prepared by diluting a solution of tin with nitro-muriatic acid, in a large quantity of distilled water, and pouring upon it a few drops of a solution of gold. When the solutions are pretty much concentrated, there is instantaneously formed a precipitate of red crimson, which in a few days changes to purple: the precipitate is light and somewhat mucilaginous; the liquor is filtrated, and the precipitate washed and dried. This matter is a compound

compound of oxide of tin and oxide of gold; the preparation of it is one of the most singular operations of chemistry, on account of the variety and the inconstancy of the phænomena which attend it. Sometimes it affords a beautiful red precipitate; sometimes its colour is only a deep violet: and what is most surprising, it happens pretty often, that the mixture of these two solutions produces no precipitate. Macquer, to whom these varieties were very well known, observes, that they depend almost always on the state of the solution of tin employed. If the solution have been hastily effected, the metal is too much oxidated, and there is too little of it contained in the solution for the acid of the solution of gold to act upon it; for he attributes the formation of the purple precipitate of *Cassius* to the action of that acid upon the tin. According to him, to succeed in this operation the solution employed must have been very slowly made, so as to contain as much tin as possible, without the metal being too much oxidated. He accordingly gives the following directions for preparing the purple precipitate. Dissolve the tin, one part after another, in an acid consisting of two parts of nitric acid and one of muriatic acid, with an equal weight of distilled water; on the other hand, dissolve with the help of heat a quantity of very pure gold in another mixed acid, consisting of three parts of nitric and one of muriatic acid. Dilute this solution of tin in an hundred parts of distilled water; divide it into two parts: add to one of them a new quantity of water, and try both of them with a drop of the solution of gold; observe then which of them affords the most beautiful red, and treat the other in the same manner with it; then pour in the solution of gold till it cease to afford a precipitate.

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Lead, iron, copper, and silver possess likewise the property of separating gold from its solution. Lead and silver separate it into a dirty dark purple precipitate. By copper and iron it is precipitated with its metallic lustre. The nitric solution of silver, and that of sulphate of iron, produce likewise a red or brown in a solution of gold.

Neutral salts act not in a very conspicuous manner on gold. Only it is observed, that melted borax poured on this metal alters its colour, and gives it a strange paleness: but nitre and muriate of soda restore it to its former state. A solution of borax poured into a solution of gold forms a precipitate of boracic acid impregnated with gold.

Sulphur is incapable of combining with gold; and this mineral is therefore employed to separate such other metals as happen to be united with gold, especially silver. The alloy is melted in a crucible; when it is fully melted, flowers of sulphur, or sulphur in powder, are cast on its surface: the sulphur melting and combining with the silver thus forms a blackish scoria which swims above the gold. It is to be observed, that the two metals are never entirely separated by this operation, which is called *dry parting*; and that it is applied only to lumps of silver containing too little gold to be worth the expence of parting by aquafortis.

Alkaline sulphure dissolves gold entirely. Stahl even thinks that it was by such a process that Moses made the Israelites drink the golden calf that they had worshipped. In making this combination, a mixture consisting of equal parts of sulphur and potash is hastily melted with a quantity of gold leaf, amounting to an eighth

eight part of the weight of the whole mass. This melted matter is poured upon a surface of porphyry, pulverized, and diluted with hot distilled water; it now forms a yellowish green solution, containing an auriferous sulphure of potash. This metal may be precipitated by means of acids, and separated from the sulphur precipitated together with it by heating it in open vessels.

Gold combines with most metallic matters; and in its combinations with them exhibits a number of important phenomena.

It unites with arsenic. This semi-metal renders its contexture brittle, and its colour very pale. It is scarce possible to separate the arsenic entirely from this mixture; the gold seems to render it more fixed in its nature.

We are unacquainted with any alloy of this metal with cobalt. It combines with bismuth, which renders it white and brittle; in the same manner with nickel and antimony. As these semi-metals are all easily oxidated, and mostly fusible, they are easily separated from gold by the joint action of fire and air.

Sulphur of antimony has been loudly praised by the alchemists as a purifier of gold. When this metal is alloyed with any extraneous metallic substance, such as copper, iron, or silver; on melting with it sulphure of antimony, the sulphure unites with these substances, and separates them from the gold, which is found by itself at the bottom of the vessel. This gold, however, is alloyed with antimony; it is purified by heating it to a white red. The antimony is then volatilized; a very intense fire, however, is requisite to separate it entirely; and it is observed the semi-metal carries with it some part of the gold. This process, which was so fa-

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mous among the alchemists, is in no way preferable to that in which sulphur alone is employed for the same purpose.

Gold easily unites with zinc: the mixed metal resulting from this union is the whiter and the more brittle in proportion as the quantity in which the semi-metal enters into the mixture is greater. An alloy consisting of equal parts of these two substances is of a very fine grain; and takes so beautiful a polish, that it has been recommended by Hellot as proper for making mirrors to telescopes, not liable to lose their lustre. When the zinc is separated from the gold by calcination, the oxide of the semi-metal is reddish, and carries with it a little gas, as mentioned by Stahl.

Gold has a greater affinity than any other metallic substance with mercury, and decomposes amalgams of any other metal or semi-metal with mercury. It unites with mercury in all proportions, forming with it an amalgam; which the greater the proportion of the gold is, so much the more solid and the higher coloured. This amalgam is liquefied by heat, and crystallized by cooling, like almost all the other compounds of this kind. We know not well what regular form it takes. M. Sage says, that its crystals are like feathered silver; and that when viewed through the magnifier, they appear to be quadrangular prisms. He asserts likewise, that the mercury becomes fixed in this combination. This amalgam is used to gild painters gold.

Although gold cannot be oxidated by the joint action of the air and the fires of our furnaces, it suffers that change, however, when heated with mercury. Mercury, with a forty-eighth part of gold, heated in a flat-bottomed matrafs with a very narrow neck, on a sand-bath,

bath, in the same way as oxide of mercury is heated in preparing *precipitate per se*, is itself oxidated, and causes the same phænomenon to take place on the gold. The mixture is changed into a dark red powder; and this double oxide is obtained even much sooner, according to M. Baumé, than oxide of mercury heated by itself.

Here, then, we have a metal which, though exceedingly difficult to oxidate by itself, hastens and facilitates the oxidation of another metallic matter, which does not readily suffer such a change by itself.

Gold enters very readily into union with tin and lead: either of these metals totally destroys its ductility. With iron it forms a very hard alloy, of which instruments for cutting may be formed much superior to those which are made of pure steel. This mixed metal is grey, and subject to the attraction of the magnet. Lewis proposes the use of gold to solder small pieces of steel neatly and in a very solid manner.

Gold combines with copper, which renders it red, hard, and more fusible. This alloy is fixed at different proportions for pieces of money, vessels, and toys.

Lastly, Gold combines with silver, which changes its colour, and renders it very pale. A certain difficulty, however, attend this mixture, on account of the different gravities of the two metals; as has been observed by Homberg, who saw them separate when melted together. The alloy of silver with gold forms the jeweller's green gold.

As the use of gold is very extensive, and as men have agreed to use gold and silver as common signs to represent the value of all the other productions of nature

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ture and art, it is of great importance to be able to distinguish the degree of the purity of any piece of this metal, in order to the prevention of fraud, and that all the gold which circulates in commerce may be nearly of the same intrinsic value. Just and severe laws have prescribed the particular alloy of gold to be employed in making utensils, and have pointed out the proportions requisite to give it a due degree of hardness and inflexibility for that purpose. Chemistry affords means for distinguishing with what quantity of imperfect metal gold may be at any time alloyed. The operation by which this is accomplished is called *the assay of gold*. Twenty-four grains of the gold to be assayed are cupelled for this purpose, with forty-eight grains of silver and four drachms of pure lead. The lead as it vitrifies carries off with it the imperfect metals, such as copper, &c. The gold remains, after the cupellation, in combination with the silver. These two metals again are separated by an operation which bears the name of *parting*. To part an alloy of gold and silver, is to separate the two metals by a solvent which may act upon the silver without affecting the gold. *Aqua fortis* is commonly used. The design in adding the silver to the gold was, that all the silver in the gold might be completely dissolved by the nitric acid; for experience has shown that gold must contain at least twice its weight of silver, before the nitric acid can act so as to dissolve the silver totally. As three parts of silver are often added to the gold, this operation is called *quartation*, as the gold composes in fact but one-fourth part of the mixture. The following is the way of performing this process of *parting*.

The cupelled alloy of gold and silver is first hammered flat, care being taken to heat and turn it frequently,
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that it may not split, nor separate into small parts, in consequence of becoming hard and brittle under the hammer; it is then rolled up in feathers in a spirâl form; in this form it is put into a small matrafs, and six drams of precipitated aquafortis, unmixed with muriatic acid, but diluted with half that quantity of water, are poured upon it. The vessel is exposed to a moderate heat, till the mixture begin to effervesce. The silver is soon after dissolved, and the metallic coil takes a brown colour. When the acid ceases to act, it is then decanted off; and a new quantity is poured upon the metal, and boiled on it till the silver be entirely dissolved. This second operation is called a *repetition*. The acid is then decanted off, and the spirâl piece of metal, now become very thin, and perforated with a great many holes, is washed; it is poured with water into a crucible; the water decanted off, the crucible made red hot, and the gold now displays all its properties. It is next weighed, and its weight shows the degree of the fineness of the gold. In order to know exactly what quantity of imperfect metals gold contains, any mass of gold whatever is supposed to consist of twenty-four parts, called *carats*; and to attain still greater accuracy, each carrat is divided into two and thirty parts called *thirty-seconds of a carat*. If the gold thus assayed have lost one grain in twenty-four, the mass to which it belonged is considered as gold of twenty-three carats; if a grain and an half, it is then gold of twenty carats sixteen thirty seconds, and so on. The weight made use of in assaying gold is called *sole weight*, and consists commonly of twenty-four grains; it is divided into twenty-four carats, which are again subdivided into thirty-two parts. There is also another weight used on the same

same occasion, weighing twelve grains, but divided into twenty four carats, and the carat again into thirty-two parts.

There are two important observations to be made on this operation of parting.

1. It has been thought by some chemists, that the nitric acid dissolves a little gold with the silver. M. Baumé has observed (*pages 117 and 118 of the third volume of his Chemistry*), that silver extracted from gold by parting retains in it a discernible quantity of the gold. From two pounds of fine-grain silver, which that chemist employed in making up the infernal stone, he says, that he usually separated about half a dram of gold in black powder. However, when the operation of parting is effected with an acid not too much concentrated, and the solution not carried too far, the gold then remains pure and uninjured, and there is none of it dissolved with the silver. The chemical class of the academy have been employed by administration to examine whether the nitric acid dissolves gold in the process of parting. From a long train of experiments made for this purpose, they have concluded, that, “in the process of parting, performed according to the received rules and mode of operation, the gold can never suffer the smallest loss; and that the operation is to be regarded as carried to the utmost perfection of which it is capable.” This decision, which we have extracted from the Report published by the Academy on the occasion, cannot but give full satisfaction to the public, and re-establish their confidence in the process in question.

2. Many gentlemen, skilled in assaying, and among others Schindler and Schlutter, have been of opinion, that the gold after parting still retains a little silver.

That portion they call *surcharge*, or *inter-balt*. Messrs Hellot, Macquer, and Tillet, being employed to examine the operation of the money assayers, proved this assertion to be groundless. M. Sage, however, in his Work intitled, *The Art of Assaying Gold and Silver*, page 64, asserts, that the spiral piece of gold always retains a little silver, which may be proved to exist in it by dissolving the suspected gold in twelve parts of nitro-muriatic acid: the solution being cooled, deposits in a certain space of time, often twelve hours after it is made, a little muriate of silver, in the form of a white powder.

Gold is applied to a great many uses. Its scarcity, and the high value set upon it, hinder it from being used for vessels and other utensils, like silver; but as its colour and lustre are very pleasing to the sight, it is therefore applied as a gilding or plating to the surfaces of many bodies, which it at the same time defends from the impression of the air.

The modes of gilding are very various. Gold leaf is sometimes glued on pieces of wood. Powder of gold is prepared by braying clippings of gold leaf with honey, washing them with water, and drying the particles of gold that are precipitated. Shell gold is powdered gold diluted in a mucilaginous liquor, prepared by the solution of a gum in water. The name of gold in rags is given to the following preparation: Pieces of linen steeped in a solution of gold, dried, and burnt. In making use of them, a wet cork is dipped in these ashes, and rubbed upon silver; on which the gold, being in a state of extreme division, readily fixes. We have already spoken of gilding with water gold. To make use of it, the piece of copper to be gilded must first be well scoured with sand.

and a weak aquafortis, which the workmen call *second water*; it is then immersed into a very weak solution of mercury: the mercury being precipitated, causes the amalgam of gold, which is applied to the piece, after washing it with water to carry away the acid, to adhere. When the amalgam is uniformly extended over the copper, the piece is then heated on the coals to volatilize the mercury; the operation is concluded by rubbing upon the gold gilder's wax, which is composed of *red bole*, *verdigris*, *alum*, or *martial vitriol*, with yellow wax, and heating the gilt piece for the last time to burn the wax.

The other uses of gold for toys and laces are sufficiently known, so that it is unnecessary for us to insist on them here. With respect to the medicinal virtues which have been ascribed to it; the best physicians, at present, agree in denying their existence, and think that any effects produced by the several potable preparations of gold must have been owing not to the gold, but to other matters mixed with it in the solution.

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CHAP. XXII.

Of Platina.

PLATINA, which has been known as a peculiar metal only during the last forty years, has not yet been found any where but in the gold mines of America, particularly in that of Santa Fé, near Carthagena, and in the bailiwick of Choco in Peru. The Spaniards have given it this name from *plata*, which in their language signifies silver; comparing it with that metal, of which it has in fact the colour: But the name of *white gold* appears to agree much better with its nature than that of *small silver*; for in its properties it resembles gold much more than silver.

Before the period which we have mentioned, there were some jewels of platina. But as this metal cannot be melted and wrought by itself, it is probable that the snuff-boxes, heads of canes, and other utensils of that kind sold under the name of *platina*, were mixtures of that metal with some other metallic substances;

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which, as we shall see, are necessary to render it fusible.

The platina in cabinets is in the form of small grains or spangles of a livid white, inclining at once to the colour both of iron and of silver. These grains are mixed with various extraneous substances; they are found to contain spangles of gold, blackish ferruginous sand grains which, when viewed with the magnifier, appear to be scarified like machefer, and some particles of mercury. The mercury is separated from this mixture by heating it; washing carries off the sand and the grains of iron; the iron may likewise be separated by the magnet: after this there remains nothing but gold and platina, which may be easily separated by picking as Margraf did. The grains of platina, when examined with the microscope, appear, some of them angular others round and flat, like small cakes. When hammered upon steel, most of them are found to be malleable and ductile: some of them break into pieces on such an occasion. These, when narrowly examined, are found to be hollow, and to contain within iron and a white powder. It is, doubtless, on the principle of their containing ferruginous particles, that the property which some grains of platina possess of being subject to the attraction of the loadstone, however purified from ferruginous sand, is to be accounted for.

This metal is very nearly as hard as iron. The specific gravity of platina mixed with the several extraneous matters which we have mentioned, is nearly equal to that of gold: in water it loses from a sixteenth to an eighteenth part of its weight. Buffon and Tillet, on comparing with a weight equal bulks of platina and gold reduced to grains, like those of platina found the specific gravity of platina to be one-twelfth

less than that of gold. It has been ascertained by latter experiments, that platina, after being purified by a long fusion, is superior in specific gravity to gold.

Probably platina is not found in the mines in the same form in which it is brought to us: it possibly owes its granulated form to the waters which carry it down from the hills into the plains. It is sometimes found in pretty considerable pieces: the Society of Biscay are in possession of a piece as large as a pigeon's egg. Platina, being found in places adjacent to gold mines, always contains a certain quantity of that metal. As to the mercury mixed with it, that semi-metal has been employed in extracting the gold.

Though toys made of platina have long been sold, yet the peculiar nature of the metal was unknown. Even the workers of mines had not paid any particular attention to it; but neglected a matter which had no very beautiful aspect, and was besides very difficult to work. For our first knowledge of platina, we are indebted to a Spanish mathematician, Don Antonio de Ulloa, who accompanied the French academicians that were sent on the famous journey to Peru, to ascertain the figure of the earth. In the account of his journey, published at Madrid in the year 1748, he makes mention of this metal. Charles Wood, an English metallurgist, had brought some of it from Jamaica in the year 1741. He then examined it, and gave an account of his experiments in the Philosophical Transactions for the years 1749 and 1750. At that period, the greatest chemists in Europe engaged eagerly in the examination of that new metal, the singular properties of which promised to render it so useful. Scheffer, a Swedish chemist, published an account of

his experiments on platina in the Memoirs of the academy of Stockholm for 1752. Lewis, an English chemist, made a series of experiments, almost complete, upon this metal, which may be found in the Philosophical Transactions for the year 1754. Margraff has given a detail of his experiments on this new metal in the Memoirs of the Academy of Berlin for 1757. Most of these separate memoirs have been collected into one body by M. Morin, in a work intitled, *Platina, white gold, or the eighth metal, Paris 1758*. About the same time Messrs Macquer and Baumé jointly made a great many important experiments on platina; an account of which has been published in the Memoirs of the Academy for the year 1758. Buffon, in the first volume of the Supplement to his Natural History, gives an account of a train of experiments on platina made by himself, M. de Morveau, and the Count de Milly. The baron de Sickengen likewise engaged in a series of researches on the metal of which we are now speaking; but his work has not yet been published in French. Macquer gives an extract from it in his Chemical Dictionary. M. de Lilly has given the Academy a paper on platina. The scarcity of the metal, and the difficulties attending the treatment of it, have retarded our progress towards a complete knowledge of its properties: but of late, the inquiries concerning it have been resumed with new ardour. Bergman, M. Achard, and M. de Morveau, have examined this metal in respect to several of its properties, which were before but little known.

Platina, when purified and separated by washing, picking, and muriatic acid, from the extraneous bodies which it contains, suffers no alteration of nature, only conglomerating a little more by exposure to the most intense heat. All the chemists who have examined the metal

metal agree in this. Messrs Macquer and Baumé kept platina for a number of days exposed to an unremitting fire in a-glass house, without producing any other alteration on its grains but that of making them adhere slightly together; and they were even so feebly agglutinated as to be separable barely by touching them. In these experiments they observed, that platina acquired a lustre when heated to a red white; that when very long exposed to heat, it took a dirty grey colour: and, lastly, that, as Margraff had asserted, it constantly increased in weight; which could happen only in consequence of its being reduced in part to oxide; a change which it appears liable to suffer from the action of fire. Those chemists exposed platina in the focus: it first smoked and gave out very red and lively sparks; the portions of metal exposed to the centre of the focus were next melted in about the space of a minute: the melted parts were of a sparkling white colour, and in the form of a button; they were divisible into plates with a knife. One of these masses of melted platina being struck upon steel, became flat, and was reduced into a plate without splitting or cracking: it became hard and brittle under the hammer. This fine experiment shows platina to be fusible by extreme violence of fire; to be malleable like silver and gold; and to be liable to very little alteration from the action of fire: for in all of these experiments, most of which were performed in the open air, the platina exhibited no marks of being oxidated. M. de Morveau likewise effected the fusion of platina by heating it in the wind furnace described by Macquer, with his reductive flux, consisting of eight parts of pounded glass, one part of calcined borax, and half a part of charcoal in powder. At present it is very easily melted in small portions,

without the addition of any other substance, by heating it on a burning coal with a stream of vital air: but the globules, thus melted, are so very small, that they can answer no purpose.

Platina suffers no alteration from exposure to the air: we know not, however, what might happen if it were heated red hot in contact with air: perhaps it would be oxidated, as Juncker asserts that silver and gold are when heated in this way.

This metal suffers no alteration from water, earthy matters, salino-terreous substances, or alkalis.

Neither the sulphuric acid, however highly concentrated, the nitric, nor the muriatic acid, however strong and fuming, act at all on platina, even though assisted by ebullition. Distillation, a method which chemists have always found very effectual in promoting the action of acids on metallic matters, does not effect any solution or alteration of these mixtures; only the sulphuric acid has been observed by Messrs Lewis and Baumé to tarnish the colour of grains of platina. The nitric acid again improves their lustre. Margraff says, that he obtained, by distilling this acid with platina, towards the end of the operation, a little arsenic; which phenomenon has not been observed by any other chemist. The muriatic acid produces no change on platina. Margraff likewise obtained, by distilling this acid on the metal, a white sublimate which appeared to him to be arsenic, and a reddish sublimate, the quantity of which was so small, that he could not examine its properties. All of these substances are evidently extraneous to platina. This metal, therefore, resembles gold in being but little subject to be affected by the action of simple acids; but still more in being soluble in the oxygenated muriatic and in the nitro-muriatic acid.

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The first of these acids dissolve platina with ease, and without requiring the assistance of any considerable heat: Fifteen or twenty degrees of heat in the atmosphere are sufficient to promote this solution: it takes place without any sensible effervescence; and, in other respects, perfectly resembles the following solution.

The nitro-muriatic acid, which is the most powerful solvent of platina, is that consisting of equal parts of nitric and muriatic acid. To effect this solution, which is generally more difficult than that of gold, an ounce of platina must be put into a retort, and a pound of nitro-muriatic acid, consisting of the above-mentioned proportions, mixed with it: the retort must then be put on a sand-bath and a receiver fitted to it. As soon as the acid becomes hot, there issues from it some bubbles of nitrous gas not in great plenty. The mixed acid acts calmly and slowly: this acid, however, takes at first a yellow colour, which changes to an orange, and becomes gradually deeper till it be changed into a very dark brown red. When the solution is ended, particles of reddish and black sand are found at the bottom of the retort, and separated by decanting off the liquor; the saturated liquor gradually deposites small irregular crystals of a dusky colour, which are a combination of the acid with platina. The solution of platina is among the highest coloured of metallic solutions. Though it appears to be of a deep brown colour, yet when it is diluted in water, the fluid takes at first an orange colour, which in a short time becomes yellow and very like the solution of gold: it communicates to animal matters a blackish brown tinge; which, however, is by no means purple. M. Baumé says, that platina, melted in the focus of a burning-glass and dissolved in aqua regia, never takes a brown colour, like that of platina in

in grains; and that the solution is of a deep orange yellow.

Macquer asserts, that on evaporating the solution of platina, and suffering it to cool, crystals are obtained from it much larger and much more beautiful than those which it deposits of itself when saturated. Lewis, on suffering this solution to evaporate in the open air, obtained crystals of a deep red colour tolerably large, of an irregular form, and pretty like the acid of benzoïn, but thicker. Bergman describes them as having an octohædral form. This salt is tart, but not very caustic; it melts with heat, gives out its acid, and leaves, as a residue, a dark grey oxide. The concentrated sulphuric acid produces in it a dark-coloured precipitate, which is no doubt sulphate of platina. The muriatic likewise produces in it, in the course of time, a yellowish sediment.

Alkalis and salino-terreous matters decompose the solution of platina, and precipitate the metal in the state of oxide. Carbonate of potash produces an orange precipitate in the solution of platina. This precipitate is not oxide of pure platina. Messrs Macquer and Baumé have observed, that it owes its colour to its containing a certain quantity of acid. It is therefore to be considered as a mixture of oxide of platina with muriate of potash, or a kind of triple salt. A proof of this opinion is, that when this precipitate is washed with hot water, the fluid acquires a colour by dissolving the salt of platina; and the residue is pure oxide of platina of a grey colour. Fixed alkali, boiled on this precipitate, instantly deprives it of its colour, leaving an oxide of platina of a grey white pearl colour, according to the experiments of M. Baumé. That chemist made himself certain, that the precipitate of platina is soluble in alkali;

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for on pouring a solution of the metal into a hot solution of carbonate of potash, he found no precipitate produced: and this solution, precipitated by fixed alkali, always retains, on this account, a deep colour; and platina may be easily obtained by evaporating it to dryness. Margraff discovered, that soda does not precipitate the solution of platina: but Bergman has observed, that, on putting into it a great quantity of this alkali, there is a precipitate speedily enough produced.

The alkaline Prussiates form a copious blue precipitate, which, according to M. Baumé, is owing to the iron contained in the alkali; for if the Prussiate of potash be purified, by the process which that chemist describes for the purpose, from the iron which it contains, it no longer affords any more than a few particles of blue, which are owing to the metal's still retaining a small portion of iron. Bergman asserts, that an alkaline Prussiate, highly saturated and very pure, does not precipitate the solution of platina; and that this metal is the only one not liable to be precipitated by this reagent; and therefore proposes it for separating the iron, which is always in union with platina.

Caustic ammoniac produces an orange precipitate in the solution of platina. This precipitate is almost entirely saline; for water dissolves most part of it, taking a colour like that of the solution of gold. After the water has acted on this precipitate, there remains a blackish substance, which appears to be ferruginous. One essential difference between the precipitate of platina and that of gold by ammoniac, is, that the former is not fulminating like the latter.

Nutgall, or rather the gallic acid, produces, in the solution of platina, a deep green precipitate, which becomes gradually pale by rest.

All precipitates of the solution of platina obtained by

alkaline matters, are unfit for vitrifying and colouring glass by furnace fires. In the attempts made by Messrs Lewis and Baumé to accomplish this, the platina was always reduced to grains, which were arranged in ramifications, or a kind of chequer work. Platina may be obtained in a sort of button, by exposing these precipitates to heat, together with some reductive fluxes, such as borax, cream of tartar, glass, &c. Messrs Macquer and Baumé melted in five and thirty minutes, at a forge fire blown by two strong bellows, a precipitate of platina mixed with these fluxes. They obtained in a hard blackish glass, like bottle-glass, a brilliant button of platina, which appeared to have been in fusion. This button was not ductile: it broke into two pieces; in consequence of which it was observed to be hollow within. It was nearly of the same hardness with forged iron, and made deep scratches in gold, in copper, and even in iron. Notwithstanding what we have observed of precipitates of platina, as not being liable to vitrify or mix with glass, Baumé melted them into a vitriform matter by two different processes. The precipitate of platina, mixed with calcined borax and a very fusible white glass, and exposed for six and thirty hours to the heat of the hottest place of a furnace for pottery, afforded him a greenish glass, inclining to yellow, and containing no globules of reduced metal. This glass being treated anew with cream of tartar, gypsum, and potash, was thoroughly melted, but contained small globules of platina dispersed through it. M. Baumé separated them by washing, and found them to be ductile. He then, in conjunction with M. Macquer, exposed precipitate of platina in the focus of the same burning-glass with which they had melted the metal. The precipitate emitted a very thick luminous smoke, which

which diffused a strong smell of nitro-muriatic acid: it lost its red colour, and resumed the natural colour of platina; and it melted into a glossy sparkling button: which button was an opaque vitrescent matter of an hyacinth colour on the surface, and blackish internally, and may be considered as a real glass of platina. It is, however, necessary for us to observe, that the saline matters with which it was impregnated, must, without doubt, have contributed to its vitrification.

The precipitate of platina does not appear to be soluble in simple acids; but it dissolves readily in the nitro-muriatic acid, to which it communicates only an orange colour; never a brown like platina in grains.

The solution of platina is not precipitated by alkaline or perfect neutral salts; but ammoniacal muriate produces in it a copious precipitate. We know not yet well what passes on this occasion. It appears, that the orange colour obtained by pouring a solution of ammoniacal muriate into a solution of platina, is a true saline substance entirely soluble in water. This precipitate possesses one property of no small importance, which was first observed by M. de Lisle: it melts alone without any addition in a good strong furnace fire, or in the fire of a common forge. The platina melted by this process is a sparkling button of considerable density and closeness of grain, but not malleable, and not liable to become ductile unless when exposed to a pretty strong heat. Macquer is of opinion, that the same thing takes place in this instance of fusion, as when grains of platina are exposed by themselves to the action of a strong fire; and that what is effected is nothing but an agglutination of the particles softened by the heat; which being much more minute than grains of platina, are brought more completely into contact with

with each other than those grains can be; in consequence of which, though no real fusion take place, yet the grain of the metal is much closer in this than in the former case. It appears, however, that as platina in grains is liable to melt in a burning-glass, and acquires, by that means, considerable ductility; so the precipitate of this metal produced by ammoniacal muriate, being in a state of extreme division, may be also melted; and if the precipitate acquire not by fusion the same ductility with platina melted by the rays of the sun, this is perhaps owing to its still retaining some matter which intermixed with it when it was precipitated; but may be separated from it by the action of fire.

Margraff dissolved platina in *aqua regia*, consisting of sixteen parts of nitric acid with one of ammoniacal muriate. On distilling this solution to dryness, and even till the retort became red hot, a dark salt was sublimated, and the residue was a reddish powder. It is not known whether the solution of platina in simple *aqua regia*, that is, *aqua regia* consisting of nitric and muriatic acid, would afford the same sublimate by distillation.

Messrs Margraff, Baumé, and Lewis, mixed the solution of platina with solutions of the other metallic substances. From these experiments it appears, that almost all metals precipitate platina in a brick-red or a brown powder; and that, agreeably to what happens to most other metals, none of these precipitates possesses the properties of a metal. In this there is an analogy between gold and platina: with tin, however, platina does not give a purple, but a brown precipitate, inclining to red. With respect to the effects which the several metallic solutions produce on the solution of platina, we shall only observe, that solutions of bismuth and lead by the

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the nitric acid, of iron and copper by any of the acids, and of gold by aqua regia, produce, none of them, any precipitate in the solution of platina, according to Margraff: but again, solutions of arseniate of potash, of nitrate of zinc, and nitrate of silver, are capable of precipitating the solution of platina: with the first it yields a scanty crystallized precipitate of a beautiful golden colour; with the second, an orange-red matter; and with the third, a yellow matter. These different precipitates have not been yet carefully examined, nor is it known by what decomposition they are produced.

Scarce any of the neutral salts acts upon platina. Margraff heated platina with sulphate of potash and sulphate of soda at a strong fire. The salts were melted, but the platina remained in grains without alteration; only it communicated a faint reddish colour to the saline matters, which it was enabled to do, no doubt, by means of the iron mixed with it.

Nitre, according to the experiments of Lewis and Margraff, alters platina in a singular manner. No detonation takes place when a mixture of these two substances is cast into a crucible; but when a mixture, consisting of one part of platina and two of nitre, is exposed for a considerable time to an intense heat, as Lewis exposed it for three days and three nights successively, the metal takes a rusty appearance. If this mixture be boiled in water, the fluid dissolves the alkali, which carries with it a brownish powder; and the platina separated by this washing is found to be one-third less than the original quantity. The brown powder may be separated from the alkali by filtration. This powder appears to be a kind of oxide of platina mixed with a little oxide of iron. Lewis caused it to take a whitish grey colour, by distilling it many times
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ſucceſſively with ammoniacal muriate. Margraff repeated this valuable experiment, and has added two important facts; platina combined with alkali of nitre, and diluted in a certain quantity of water, forms a jelly; A portion of the metal ſeparated from this jelly by dilution in water and filtration takes a black colour like pitch. From theſe circumſtances it appears that the platina ſuffers in this proceſs ſome great alteration; and it is to be wiſhed that theſe experiments were farther proſecuted, in order to determine whether by repeated oxidation with nitre, this metal might be wholly reduced to a brown powder; as alſo to aſcertain the ſtate of the platina thus oxidated.

Muriate of potaſh or ſoda, borax or earthy ſalts, produce, none of them, any alteration on platina, nor contribute in any degree to its fuſion. Ammoniacal muriate ſublimated with this metal affords a ſmall quantity of martial flowers, on account of the iron contained in the platina.

Chemiſts are not agreed with regard to the mutual action of arſenic and platina. Scheffer firſt gave out that arſenic acted as a flux to platina; but the experiment ſucceeded only in part with Lewis, and did not ſucceed at all with Margraff, Macquer, and M. Baumé. This experiment has been ſince repeated; and it is now eſtabliſhed as a fact, that arſenic does cauſe platina to melt very readily; and that the mixture produced by this fuſion is exceedingly brittle. When the arſenic is ſeparated by roaſting, and the perfect metal expoſed to a continued heat, the latter becomes ductile. By this proceſs M. Achard and M. Morveau have accompliſhed the making of crucibles of platina, by melting it a ſecond time in moulds.

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No attempt has yet been made to combine cobalt, nickel, or manganese with platina.

This perfect metal enters readily enough into combination with bismuth; which renders it fusible, and the more so the greater the quantity of the bismuth. This mixture is brittle; it becomes yellow, purple, and blackish in the air; it cannot be cupelled without the greatest difficulty; the mass has alway very little ductility.

Platina easily melts with antimony: the product is a brittle metal with facets, from which the antimony cannot be separated by the action of fire, and which still retains, whatever means may be used for its separation, so much of the semi-metal as is sufficient to destroy the gravity and ductility of the platina.

Zinc renders platina very fusible, and combines very easily with it; the mixture is brittle, and resists the file: it inclines to blue in colour, when the platina is more copious than the zinc. These two metallic matters are separable by the action of fire which volatilizes the zinc; platina, however, always retains a little of it.

Platina does not combine with mercury; and though triturated together for hours, these two metallic matters cannot be formed into an amalgam. It is also known, that in America, mercury is employed to separate platina from gold. Various intermedia, such as water, which Messrs Lewis and Baumé made use of, and nitro-muriatic acid which M. Scheffer employed, contribute nothing to the union of platina with mercury. It resembles iron in this property, as also in colour and hardness.

Platina readily combines with tin. The mixture is very fusible, and melts into a flowing liquid. It is so

brittle as to break even by a blow, when the two metals are united in equal parts. When tin is in the proportion of twelve or more parts to one of the platina, the mixed metal is then sufficiently ductile; but its grain is coarse, and it becomes yellow in the air. The platina diminishes the ductility of the tin in an amazing degree, and it does not appear that it can be separated from this mixture. However, when well polished, it remains long in the air without suffering alteration. Lewis, to whom we owe most of our knowledge concerning the mixtures of platina, oxidated the metal, and dissolved it in muriatic acid by means of tin.

Lead and platina combine very well by fusion; but a stronger fire is requisite to melt them than to melt the foregoing mixture. The platina destroys the ductility of the lead. From the combination of these two metals there results a mixed metal, nearly of a purple colour, more or less brittle according to the proportions of the platina, striated and granulated in its fracture, and liable to alter very readily in the air. Cupellation of lead was one of the most important experiments to be made on platina; for this was the only operation that could be expected to separate from it such extraneous matters as it might contain. Lewis and several other chemists in vain attempted to cupel platina in common cupelling furnaces, whatever the degree of the heat employed in those furnaces. On account of the excess of the lead, it is vitrified and absorbed in the beginning of the operation; but the platina soon becomes fixed, and the progress of the operation stops; the perfect metal remains in union with a portion of the lead, and is without ductility. Messrs Macquer and Baumé effected the complete cupellation of platina by exposing an ounce

of this metal with two ounces of lead to the heat of the hottest place of the porcelain furnace at Seves. The wood fire which they kindled in it burnt for fifty hours uninterruptedly. At the end of that time the platina lay flat upon the cupel: its upper surface was dark and crivelled, and was easily separable from the rest; its under surface was brilliant; and what is of most importance, it was now sufficiently malleable. These experiments ascertained, by every possible means, the platina to be very pure, and unmixed with lead. M. de Morveau likewise succeeded in cupelling a mixture of a dram of platina with two drams of lead in Macquer's wind furnace. This operation, which was four times repeated, lasted eleven hours. M. de Morveau obtained a button of platina, not adhesive, uniform, coloured like tin, somewhat rough, weighing exactly a dram, and not subject to the attraction of the magnet. This is therefore a convenient process, by which platina may be melted into plates that may be wrought in the forge; and of consequence made into various utensils of great value for their hardness and unalterability. M. Baumé likewise observed it to possess this valuable property, that different pieces of it may be foldered and wrought together like iron, without the intervention of a third metal. After heating two pieces of platina that had been cupelled in the furnace of Seves to a white red, he put the one upon the other, and struck them with a hammer; and by this management the two pieces were as sufficiently and solidly foldered as any two pieces of iron could have been. It is not necessary that we should insist long on this experiment, to show what advantages the arts may derive from it.

Lewis could not obtain a mixture of forged iron and platina. A mixed metal of this kind would possess at

once the hardness of tempered steel, and a considerable degree of ductility; it would not at least be so brittle as steel. The English, whom we have cited, melted a mixture of cast iron and platina. The alloy was so hard that the file could make no impression upon it: it had little ductility; but when red hot, it broke with a smooth fracture.

Platina communicates hardness to copper, and melts with it easily enough. This mixture is ductile when the proportion of the copper is three or four more than that of the platina. It takes a fine polish, and is not liable to be tarnished in the course of ten years.

Platina destroys in part the ductility of silver, increases its hardness, and tarnishes its colour. The mixture is very difficult to melt. The two metals are separable by fusion and rest. Lewis observed, that the silver melted with platina is dashed with a kind of explosion against the sides of the vessel. This phenomenon seems to be effected solely by the silver; for M. d'Arce saw that metal burst bowls of porcelain in which it was inclosed, and spring out of those vessels in consequence of the action of fire upon it.

A very strong heat is requisite to make platina combine properly with gold. It greatly alters the colour of that metal, at least if its quantity be not very small; for instance, a forty-seventh part of platina, and all proportions under that, produce but little alteration on the colour of gold. Platina scarce diminishes the ductility of gold; it is even one of those metals which have the least influence on gold this way. The gravity of platina being greater than that of gold, might be an encouragement to fraud; and the Spanish ministers have therefore prohibited the exportation of the metal.

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metal. However, since chemical methods of distinguishing when gold is alloyed with platina have been discovered, these fears are now vain; and it is much to be wished that platina were permitted to be an article of commerce, that so we might obtain the use of a new metal which promises to be so serviceable.

The solution of ammoniacal muriate possesses, as we have observed, the property of precipitating platina. When therefore gold is suspected to be alloyed with platina, a solution of it in *aqua-regia* may be assayed with a solution of ammoniacal muriate. If it contain any platina, however little, an orange or reddish precipitate will be produced: if there is no precipitate produced, that circumstance is a proof that the gold contains no ammoniac. If the valuable properties of platina should one day render it more scarce and more esteemed than gold, neither will we then be in danger of having alloys of gold with platina imposed on us for pure platina; for a solution of sulphate of iron, which possesses the property of precipitating a solution of gold without affecting platina, might be used as a test to prevent such imposition. A plate of tin immersed into a solution of platina alloyed with gold, would likewise detect the presence of the latter metal, by becoming coated with a purple precipitate; whereas platina, by itself, gives it only a dirty brown colour inclining to red. Besides, the precipitate of platina does not colour glass, whereas the precipitate of gold gives it a purple colour.

All those properties of platina which we have examined prove it to be a peculiar metal. Its possessing in so low a degree the properties of ductility and fusibility, which has been considered by some persons as a strong objection against this opinion, is not sufficient to

justify the refusing it that character which we have ascribed to it: for perhaps the difference between the fusibility of platina and that of forged iron, is not so considerable as the difference between the fusibility of forged iron and that of lead: and its inductility may be considered as owing to its having never yet been completely melted. With respect to the opinion of those philosophers who think platina a natural alloy of gold with iron, however ingenious and satisfactory it may appear, cannot be admitted till such time as platina shall be separated by an exact analysis into these two metals, and till it be better imitated than at present by an artificial mixture of gold with iron. Lastly, Macquer has urged a very strong objection against this last opinion, by observing that the more thoroughly platina is purified from iron, the more remote does it appear in its exterior characteristics and properties from the nature of gold.

It may be easily conceived with what advantages the use of this precious metal in commerce would be attended, as it possesses, with the durability of gold, nearly the hardness of iron, and is proof against the action of the most violent fire, and the most concentrated acids. It would, doubtless, be of the highest utility both to chemistry and to the arts.

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[C H A P. XXIII.

Genus VI. *Bitumens in general* *.

BITUMENS are combustible matters, either solid, soft, or fluid, of a strong, acrid, aromatic smell, and apparently of a much more compound nature than any of the bodies belonging to the mineral kingdom which we have yet examined. They are found either in strata in the bowels of the earth, or dropping from rocks, or swimming on the surface of waters. They generally burn with a rapid flame when heated in contact with air, like those matters formed from the organs of animals and vegetables, which are called *oils*. They admit of being much more exactly analysed than earthy, saline, or metallic matters; for the action of fire alters them in a singular manner, extracting their principles, which as they are volatilized react on each

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* The reader may here recollect that we divided combustible mineral matters into five genera; diamond, hydrogenous gas, sulphur, metals, and bitumens. **A.**

other. In this respect there is an analogy between bitumens and vegetable substances. They afford by distillation an odorate water or phlegm, more or less coloured and saline; an acid generally concrete; sometimes ammoniac; and oils which, tho' at first light, become more and more thick and coloured as the distillation is continued, and the strength of the fire increased. After this analysis, there remains a coal of a greater or a less bulk, dense, light, porous, brilliant, or compact, according to the particular nature of the bitumen. This analysis is a proof that these inflammable bodies have originated from animal or vegetable matters; as we shall relate more at large when we give the history of their properties.

Bitumens suffer some alterations from light; when fluid, their colour is rendered deeper, and their smell modified in transparent vessels. The air renders them thicker by a gradual evaporation of the moisture which they contain; and the drier the atmosphere, so much the speedier is this evaporation. Their odorous principle, or spiritus rector, is at the same time gradually dissipated; and from fluid they become by degrees tenacious and solid. But this latter alteration requires a long series of years.

When bitumens are boiled in water, the water does not dissolve them, but extracts their spiritus rector, and afterwards that odour which is peculiar to them. It would therefore appear that water has a greater affinity with their odorous principle than the oily matter of the bitumen; and perhaps these bodies might thus be entirely deprived of smell.

No experiments have been made to determine in what manner the salino-terreous substances act up-

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on bitumens. Both lime and pure alkalis, however, appear capable of combining with these combustible matters, and forming with them compounds soluble in water, which are called *soaps*.

We know not in what manner the mineral acids are capable of acting on bitumens. Probably they would either dissolve or burn them like oils, according to the state of concentration in which they happened to be.

Neither has the action of neutral salts, hydrogenous gas, sulphur, or metals on bitumens, been examined; and the chemical properties of these bodies are in general but very little known. This is an un-beaten path; and very useful discoveries might here be made.

Naturalists have been at much more pains in studying the origin and formation of bitumens than chemists in analysing them. Several different opinions have been entertained on that head. Some have thought combustible bodies to belong properly to the mineral kingdom, and to hold in it the same rank which oils and resins hold among organic matters. But this fancied analogy, however plausible, does not agree with facts; for we know of no substance in the mineral kingdom of an oily nature. And that opinion which ascribes the origin of bitumens to vegetable matters buried under ground, and altered by the action of mineral acids, has been much more generally received than the former. Every fact indeed concerning bitumens, concurs to prove that they have been produced from organic matters. Near them are found a great many matters still retaining an organic form. Besides, their chemical properties are those of substances formed by the action of vital powers;

ers; and they have been imitated to a certain degree by the combination of oils with concentrated sulphuric acid. In the chemical history of vegetable matters, we shall see, that this acid brought into contact with essential oils renders them hard and black, and communicates to them a strong pungent smell like that of bitumens. But are these bodies formed solely from vegetables buried under ground, as has been asserted by most naturalists? Do animal matters in the same situation never contribute to the formation of bitumens? One objection which may be urged against the opinion that represents bitumens as originating solely from particular vegetable bodies, is the great disproportion between the masses of bitumen found in the earth and the wood or trees found near them, and still more the trifling quantity of oily matters contained in those vegetable substances. And farther, the abundance of these combustible bodies in places where scarce any remains of vegetable matters appear but the exuviae of animals, are found in heaps above the bitumens, lead us to think that these latter organic beings have contributed greatly, perhaps more than vegetables, to the formation of certain bituminous substances. We may likewise observe, that the successive strata, in which some continuous masses of bitumen are found arranged in the interior parts of the globe, indicate those masses to have been deposited slowly, and by water; and that the date of their formation corresponds to the period in which such immense masses of shells and other marine bodies would be formed by the sea. They have therefore been in a fluid state, and have become hard in the course of time, in consequence of being exposed to the action of saline or other substances abounding in the interior parts of the earth. Such is

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the opinion which M. Parmentier, member of the College of Pharmacy, has embraced concerning the origin of mineral coal, in a Memoir which he read before that Society at the opening of their course of lectures. The oils and fats of marine animals appear therefore to be part of the materials which nature employs in the formation of certain bitumens: and there are others again, the origin of which is evidently from vegetables, and which have been produced from resins or essential oils, buried and altered in the earth.

The number of bitumens is very considerable. Naturalists have arranged them under various genera. Considered chemically, they merit rather to be considered as so many species; for the same chemical characteristics are common to them all. Some of them are liquid; others of a soft consistency: there are others solid, and among these some so hard as to be susceptible of polish; others friable. We know of five species, considerably distinct from one another. These are amber, the asphaltes or bitumen of Judæa, jet, pit-coal, and petroleum; and we are to give their history. Ambergris we do not consider as a bitumen, but as an animal product.

C H A P.

C H A P. XIV.

Species I. *Of Amber, and its Acid.*

THIS substance is, in external appearance, one of the most beautiful of bituminous matters: it exists in irregular fragments of a yellow or a brown colour, either transparent or opaque, and composed of layers or scales. It takes a very fine polish. After being rubbed for some time, it becomes electric, and attracts straws. The ancients, who knew amber to possess this property, gave it the name of *electrum*; and hence the word *electricity*.

The consistency of this bitumen is pretty hard, nearly equal to that of certain stones: which has induced several authors, particularly Hartman a naturalist, who lived about the end of the last century, to rank it among precious stones. It is, however, brittle and friable. When pulverized, it diffuses an agreeable enough smell. It is often found to contain insects in a good state of preservation; a circumstance which proves

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proves that it has been in a liquid state, and in that state has inclosed these bodies. It is usually buried under ground at various depths; it is found under coloured sand, in small incoherent masses, on beds of pyritous earth; above it is found wood containing a blackish bituminous matter. From these circumstances it is thought to be formed from a resinous substance altered by the sulphuric acid of the pyrites. It also floats on sea-coasts. It is gathered on the shores of the Baltic in Ducal Prussia. The hills of Provence, near the town of Sisteron, the Marquisate of Ancona, and the Duchy of Spoleto, in Italy, Sicily, Poland, Sweden, and various other countries, likewise afford this substance. This bituminous substance is distinguished into a good many varieties, by its colour, texture, transparency, or opacity. Wallerius reduces them to the following

Varieties.

1. White transparent amber.
2. Pale yellow transparent amber.
3. Citron yellow transparent amber.
4. Transparent amber of a golden yellow colour. *Chryso-electrum* of the ancients.
5. Dark red transparent amber.
6. White opaque amber. *Leucelectrum*.
7. Yellow opaque amber.
8. Brown opaque amber.
9. Amber coloured green or blue by extraneous matters.
10. Veined.

Were we to take notice of all the accidental appearances which are observed in the interior parts of pieces
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of amber, we might extend these varieties to a much more considerable number. But, in regard to the price demanded for pieces of amber, on account of their size, their transparency, and their containing insects in a fine state of preservation, it is proper to warn people that they may be imposed upon, as many persons know how to render it transparent or colour it at pleasure, as well as to soften it to such a degree, that extraneous bodies may be introduced into it. Wallerius informs us, that gold-coloured amber always owes its transparency to nature; and that amber made transparent by art is always of a pale colour.

Although it be highly probable that this bitumen originates from resinous vegetable matters; yet several naturalists have entertained different opinions concerning its formation. Some have thought it to be urine of certain quadrupeds congealed and hardened; others have imagined it a juice of the earth extracted and carried off by the sea, which being driven by the waters on the shore, is there dried and hardened by the rays of the sun. This class of naturalists call it a peculiar mineral juice. Such was the opinion of an ancient naturalist of the name of Philemon, quoted by Pliny. It has been in modern times revived by George Agricola. Frederic Hoffman thought it to consist of a light oil, separated by heat from bituminous wood, and thickened with the acid of vitriol. This opinion of Hoffman's, however, cannot be admitted: it is not easy to imagine how an oil separated in the bowels of the earth could happen to contain animals that are known to live only on the surface. Till of late, amber was thought to be a resinous juice which dropped at first in a fluid state from certain trees: this juice, it was thought, having been, by some convulsion of the earth,
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buried under ground, had been there hardened and impregnated with saline mineral vapours. But there is no appearance of its having been altered by concentrated acids; for experience shows, that such acids would have blackened it, and reduced it to a carbonaceous state. Pliny thought amber to be nothing but the resin of the pine tree condensed by cold. M. Girtanner thinks it to be a vegetable oil concreted by the acid of ants. The *formica rufa* of Linnæus is, according to this author, the species which prepares it. These insects inhabit old forests of fir trees, where there is fossil amber found, which is ductile, like liquid wax, but becomes dry in the air.

A considerable degree of heat is necessary to liquefy amber: it becomes soft and swells a good deal. When heated in contact with air it takes fire, and diffuses a very thick and strong smelling smoke. Its flame is yellowish, variegated with green and blue. After its combustion there remains a sparkling black coal, which affords, by incineration, a very small quantity of brown earth. Bourdelin, in his Memoir on Amber (*Academy*, 1742), relates, that he obtained only eighteen grains of this earth from two pounds of amber burnt in a roasting pot. Half a pound of the same bitumen, burnt and calcined in a crucible, afforded, in a second operation, twelve grains of earthy residue; from which, by means of the magnet, he extracted iron.

Amber distilled in a retort, by a fire gradually applied, gives at first a phlegm which takes a red colour, and is plainly of an acid nature. This acid spirit retains a strong smell of amber; there passes next a volatile acid salt, which crystallizes in the neck of the retort into small white or yellowish needles; next after this salt there comes a white light oil of a very lively smell.

smell. This oil gradually takes a colour as the fire becomes stronger ; and at length becomes brown, blackish, thick, and viscid, like empyreumatic oils. While these two oils are passing, there is a certain quantity of volatile salt sublimated, which becomes gradually more and more coloured. After the operation, there remains in the retort a black mass fixed on its bottom, brittle, and similar to the bitumen of Judæa. George Agricola made this observation three centuries ago on the residue of distilled amber. When the operation is conducted with a moderate fire, judiciously applied, and the quantity of the amber not inconsiderable, these products may be obtained by changing the receiver. They are commonly received all in one receiver, and afterwards rectified by a moderate heat. The spirit loses its colour in part by this rectification. The oil, the reason of which becoming black towards the end of the operation is because it carries with it a portion of carbonaceous matter, and the acid reacts on its principles, may be rendered very white and very light by repeated distillation. Rouelle, the elder, has given a very good process for obtaining it in this state by one operation. Put the oil with water into a glass alembic, and distil it by the heat of boiling water ; the purest portion, being the only part of the oil volatile at such a degree of heat, on account of its levity passes with the water, and is collected above it. To preserve it in this state, it must be put up in stone-vessels ; for in glass vessels, the rays of light which pass through that matter, give it, in a certain time, a yellow, or even a brown colour.

This analysis proves amber to consist of a great quantity of oil rendered concrete by an acid. It contains likewise a very small quantity of earth, the nature of which

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which has not yet been examined, and a few particles of iron.

The oil of amber appears to be much of the same nature with essential oils. It is equally volatile, and has the same smell. It is very inflammable; and appears to be fit for forming soaps with alkalis.

The volatile salt of amber was for some time considered as an alkaline salt. Glaſer, Le Fevre, Charas, and John-Maurice Hoffman, professor at Altdorf, were of this opinion. Barchusen, and Boulduc the father, both in the last century, were the first who ascertained the nature of this salt to be acid. Their discovery has been unanimously received by succeeding chemists; who have not agreed, however, concerning the particular nature of that acid. Frederick Hoffman, because amber is found in Prussia upon strata of matters among which pyrites are copiously intermixed, has inferred its salt to be vitriolic acid. Neumann appears to be of the same opinion. Bourdelin, in the memoir above quoted, relates several experiments by which he sought to ascertain the nature of this salt. He first observes, that the salt of amber, extracted by distillation, however white and pure it may appear, always contains an oily matter; to this oily substance, no doubt, it owes its smell, and that kind of combustibility which it constantly exhibits when cast on burning coals. He attempted by various means to separate that substance. We will have occasion to see, when we come to examine the nature and properties of the ardent spirit, that it could not serve his purpose. He succeeded no better by digesting fixed alkali over amber, with a view to separate from it this oily matter; the alkali only dissolved a little of the bitumen, and acquired a saltish lixivial taste like that of sea-salt. Lastly, the best means which Bourdelin could find for

combining the acid of amber entirely purified from oily matters with fixed alkali, was to detonize a mixture, consisting of two parts of nitre with one of the bitumen. The residue after this detonation he lixiviated with distilled water. The lixivium was of an amber colour: it produced in the solution of silver a white curdled precipitate; in the solution of mercury, a precipitate of the same colour. It decomposed, in like manner, several other metallic solutions; but Bourdelin considered only these two precipitations as conclusive facts. He understood them as indicating the acid of amber to be the same with that of marine salt; for these phenomena are precisely the same with those which the acid of marine salt produces in the nitric solutions of mercury and silver. The lixivium of the residue which remained after the detonation of amber with nitre being evaporated in the air, afforded a mucilaginous matter, in the middle of which oblong square crystals were by degrees deposited; which, by their form, their saltish taste, their decrepitation on burning coals, and still more their effervescence, which was considerable, and the smell of muriatic acid which exhaled from them when concentrated sulphuric acid was poured upon them, indicated, in his opinion, that they consisted of muriatic acid with a base of nitre. Notwithstanding this analysis, which, considering the time when Bourdelin made his experiments, is very accurate; the chemists, who have since examined the salt of amber, have not found it to bear any resemblance to the muriatic acid. Bergman, who seems to have adopted this opinion, gives the following account of the properties and the elective affinities of this salt. The succinic acid, or acid of amber, extracted by distillation, and purified by repeated solutions and crystallizations, forms, with

potash

potash and ammoniac, crystallizable and deliquescent neutral salts. With soda, it affords a salt which does not attract the moisture of the atmosphere: with barytes and lime it forms salts that are scarce soluble: with magnesia, a thick gum-like matter. It dissolves metallic oxides; and the succinates produced by these solutions are mostly crystallizable and permanent.

Barytes, lime, and magnesia, according to him, separate the acid of amber from alkalis. Barytes decomposes succinates of lime and magnesia; and lime-water precipitates magnesia from its combination with this acid.

The chemical properties of this bitumen have been no farther examined. We know not even how the acids would act upon it. Frederick Hoffman affirms, that it may be entirely dissolved in a lixivium of caustic alkali and in sulphuric acid. We know too, that the essential oil of amber combines with caustic ammoniac, and forms with it, simply by mixture and shaking, a sort of liquid soap of a milk-white colour and of a very pungent smell, known in pharmacy by the name of *Eau de luce*: and lastly, this same oil is known to dissolve sulphur by the heat of a sand bath, thus composing a medicine, called *succinated balsam of sulphur*.

Amber is used in medicine as an antispasmodic: it has been recommended for hysteric and hypochondriac cases, a suppression of the *menfes*, gonorrhœa, fluor albus, &c. It is made use of after being washed with warm water, and levigated to a fine powder. It is used in fortifying and resolvent fumigations, by throwing the powder on a hot brick, and directing the smoke to the place upon which you wish it to act. The volatile spirit and the salt of amber are considered as incisive, cordial, and antiseptic; they are also administered as powerful

ful diuretics. Oil of amber is applied both externally and internally for the same purposes as amber itself: it is administered in smaller dozes, on account of its acting with more energy. The succinated balsam of sulphur is given in dozes of a few drops in certain drinks, or mixed with other substances in pills, and is successful in pituitous affections or defluxions of the breast and veins, &c. A syrup, called syrup of amber, is made up of spirit of amber and opium, and is successfully used as a calming, an anodyne, and an antispasmodic medicine. *Eau de luce* is prepared by pouring a few drops of oil of amber into a phial full of caustic ammoniac, and shaking the mixture till it take a milk-white colour. It has been long used in fainting fits as a powerful stimulant: it is put to the nostrils, and it then stimulates the nerves; and, by the sneezing which it excites, the fluids are again put into motion, and the patient restored.

The most beautiful pieces of amber are cut and polished into vessels, heads of canes, necklaces, bracelets, snuff-boxes, &c. But this species of toys is no longer valued among us, since diamonds and cut stones have been known and brought into use. They are sent, however, to Persia and China, and to other foreign countries, where they are still valued as the greatest curiosities. Wallerius says, that the most transparent pieces may be used for microscopes, burning glasses, prisms, &c. It is affirmed, that the late King of Prussia was possessed of an amber burning-glass a foot in diameter; and that in the cabinet of the Duke of Tuscany there is a column of amber ten feet high, and of a most beautiful lustre. Two pieces of this bituminous substance may be joined together, by dipping them into a solution of potash, heating them, and applying them to each other.

C H A P.

C H A P. XXV.

Species II. *Of Asphaltus.*

ASPHALTUS, or *bitumen of Judea*, called also *funeral gum*, *amber of Sodom*, *mountain-pitch*, *balm of mummies*, &c. is a black bituminous substance, ponderous, solid, and considerably brilliant. It breaks easily, and its fracture is vitreous. A thin plate of this bitumen appears red between the eye and the light. Asphaltus, when cold, has no smell; when rubbed, it emits a faint smell. It is found on the waters of the lake Asphaltites, or the Dead Sea, in Judea, near which stood the ancient cities of Sodom and Gomorrha. The inhabitants of the adjacent country finding the smell of the bitumen which gather on the waters of that lake troublesome, and the bitumen itself a profitable article of commerce, collect and expose it to sale. Lemery, in his Dictionary of Drugs, says that asphaltus sweats like liquid pitch out of the earth covered by the Dead Sea; and rising above the waters, is there condensed by

the heat of the sun, and the action of a salt which abounds in those waters. It is also found on many lakes in China.

The asphaltus of commerce, M. Valmont de Bomare tells us, is obtained from the mines of Daunemore, and especially in the principality of Neufchatel and Wal-lengin. According to that naturalist, it is of two colours, either blackish or greyish. But such asphaltus is far from being pure; it seems to be only earth hardened and intermixed with bitumen which has penetrated through it.

Naturalists are divided concerning the origin of asphaltus, as well as concerning the other bitumens. Some think it a mineral product, formed of an acid united in the interior parts of the earth, with some fat matter. Others think it a resinous vegetable matter, that has been buried under ground and altered by mineral acids. The most general and probable opinion is, that it has been produced in the same way as amber, and is actually nothing but amber altered by the action of subterraneous fire. The ground of this opinion is, that amber, when melted and deprived of a part of its oil, becomes black, dry, brittle, and in all respects like asphaltus. But it can be finally established only by a comparative analysis of this residue of amber and asphaltus. Asphaltus has not yet been examined with such exactness as will allow us to presume on the analogy between them.

Asphaltus, when exposed to fire, becomes liquid, swells, and burns with a thick flame and smoke; the smell of which is strong, acrid, and disagreeable. By distillation, it affords a coloured oil, like brown petroleum, and an acid phlegm.

Asphaltus is used by the Arabians and Indians in the same

same way as pitch for coating their vessels. It enters into the composition of the black varnishes which we get from China, and of those artificial fires which burn on water. The Egyptians used it in embalming dead bodies; but it was employed for that purpose only by the poor, who could not afford to purchase dearer antiseptic matters. Wallerius asserts, that the merchants prepare a sort of asphaltus of thick pitch, or by mixing and melting pitch with asphaltus from Judea. But the fraud may be detected by means of alcohol, which entirely dissolves pitch, but produces no change on asphaltus, only taking itself from it a pale yellow colour.

C H A P.

C H A P. XXVI.

Species III. *Of Jet.*

JET, in Latin *gagas*, called by Pliny *black amber*, by Strabo, &c. *pangitis*, is a black bituminous substance, compact, hard like some stones, brilliant and vitreous in its fracture, and susceptible of a fine polish. After being rubbed for some time, it attracts hard bodies, and, like amber, appears to be electric. It has no smell: when heated, it acquires a smell nearly the same with that of the bitumen of Judea.

Jet is found in France, in Provence, and in the country of Foix. There is also a quarry of it which is wrought at Belestat in the Pyrenees. It is found too in Sweden, in Germany, and in Ireland. The quarries of jet are in strata; they likewise contain pyrites and pit coal, and most of the other bitumens.

This bitumen, when exposed to a strong heat, becomes soft and melts; it burns with a foetid odour. By distillation it affords oil and an acid liquor.

Of the several opinions which have been advanced concerning the formation of jet, the most probable is that which represents it as asphaltus condensed and hardened by length of time. It has been adopted by the learned Wallerius.

Jet is used for mourning toys. At Wirtemberg it is wrought into bracelets, buttons, boxes, &c.

C H A P.

C H A P. XXVII.

Species IV. *Of Pit-coal.*

THE name of *fossil coal*, *pit coal*, *stone coal*, *lithantrax*, &c. is given to a black bituminous matter, foliated, either glistering or dull, brittle, and inferior in consistency and purity to the bitumens which we have been describing.

This bitumen derives its name from its combustibility, and the use to which it is in many countries applied. It is found in the interior parts of the earth, under stones of various degrees of hardness, and under aluminous and pyritous schisti. These schisti always bear impressions of vegetables belonging to the fern tribe, which have been observed by Bernard de Jussieu to be mostly exotics. Pit-coal is sometimes nearer to, sometimes more remote from, the surface of the earth. Its disposition is always in horizontal or inclined layers; ofteneft in inclined. The beds or strata which it composes, differ from each other in consistency, colour, gravity, &c. Over this bitumen, strata
of

of fossil shells and madrepores, varying in extent, are often observed; a circumstance which has led some moderns, particularly M. Parmentier, to think that it has been formed in the sea by the deposition and alteration of the oily or fat matters of marine animals. Most naturalists think it the residue of wood deposited in the ground, and altered by acids.

Quarries of fossil coal are wrought like mines of metal by digging into them pits and galleries, and hewing down the coal with a sort of pickaxes. The colliers are often in danger of losing their lives by the elastic fluids disengaged. This mephitic, which they call *choak damp*, puts out their lights, and seems to be carbonic acid gas. There likewise gathers in these mines a kind of inflammable gas, the effects of which are very noxious, and which sometimes produces very dangerous explosions.

Fossil coal is very plentiful in nature. It is found in England, Scotland, Ireland, Hainault, the territory of Liege, Sweden, Bohemia, Saxony, &c. Several provinces of France afford great quantities, particularly Burgundy, the district of Lyons, Forez, Auvergne, Normandy, &c.

Fossil coal is distinguished by its hardness or friability into stone-coal or earth-coal. The manner of its burning, and the phenomena which it exhibits during combustion, afford the best characteristics for distinguishing it into different species. Wallerius arranges fossil coals, considered in this point of view, under three species. 1. The scaly coal, which remains black after combustion. 2. The compact foliated coal, which affords, after being burnt, a spongy matter like scorix. 3. Fibrous pit-coal, resembling wood, which is reduced to ashes by combustion.

This

This bitumen, when heated in contact with a burning body and air, takes fire; the more slowly, and with the greater difficulty, the more ponderous and compact it is: when it has once taken fire, it diffuses a lively lasting heat, and burns long before being consumed. It may be quenched and burnt again, for a number of times successively. The inflammable matter contained in it appears to be very dense, and in a manner fixed in some other incombustible substance which opposes its combustion. It exhales as it burns a peculiar odour; which, however, is no way sulphureous, if the coal be very pure, and contain no pyritous matter. The combustion of this bitumen seems very analogous to that of organic matters, as it may be stopped and afterwards renewed. The most volatile part of the oily combustible matter contained in pit-coal is indeed burnt and dissipated when it is first exposed to the action of heat; and if, after the whole of that principle is dissipated, the combustion be stopped, the bitumen retains only the most fixed and the least inflammable part of its oil, in a truly carbonaceous state, and combined with an earthy base. It is by a process of this nature that the English prepare their *coaks*, which are nothing but pit-coals deprived by the action of fire of the fluid part of their oil.

We may easily observe what happens in this operation, by heating this bitumen in close vessels, and in a distillatory apparatus. It affords in this way an alkaline phlegm, concrete ammoniacal carbonate, and an oil which, as the distillation proceeds, takes a deeper colour, and becomes more ponderous. There passes at the same time a large quantity of an elastic inflammable fluid, which is commonly thought to be oil in vapours, but is properly hydrogenous gas, mixed with azotic gas,

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gas, with carbonaceous matter dissolved in it, and with carbonic acid gas. There remains in the retort a scorified carbonaceous matter, which is still susceptible of combustion, and is the same with the English *coak*. Observing carefully the action of fire on pure pit-coal, we perceive the coal to be first softened, and in a manner half melted; but as this property might render it unsuitable for the melting of ores, it must be deprived of it before it be applied to that purpose. After taking from it the principle which renders it liable to soften, that is the oil which it contains in great abundance, and thus reducing it to a state nearly the same with that of vegetable coal, it then becomes suitable for the fusion of ores. Let us not forget to observe, that the ammoniac which pit-coal affords in such considerable quantity, affords an argument in favour of that opinion which represents this bitumen as produced from animal matters; for, as we shall hereafter see, bodies belonging to the animal kingdom always afford this salt when distilled. This analysis is performed in the great way in various places in England; and the several products are collected in a peculiar distillatory apparatus. The oil is used for pitch; the ammoniac is used in the composition of ammoniacal muriate; and the residue is a very good *coak*. M. Faujas de Saint Fond has imported this useful art into France; and the trials which he has made in the king's garden have succeeded very well in the small way: We have as yet no establishment for carrying it on in the great way*.

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* The English reader will here recollect the patriotic exertions of the Earl of Dundonald to establish works of this kind in Britain.

Pit-coal is highly useful in countries destitute of wood. It is used as a combustible matter; and the dangerous effects which have been ascribed to it are quite imaginary. The sulphureous vapour which it has been said to diffuse has no existence; for chemists have universally found, by the most exact analysis, that pure mineral coal contains not an atom of sulphur. From this we see the ignorance and imposture of some people who have pretended to give processes for purifying coals of sulphur. Another consideration which should induce us to make as much use as possible of coals in France is, that such enormous quantities of charcoal are consumed in the working of ores, that our wood is likely to fail one day or another; it is especially in works of that kind we should try the use of pit-coal, as the English have long done. It is already beginning to be used in various manufactories among us; and in the famous founderies of iron at Creusot, near Montcenis in Burgundy, there is a great instance of its application to these purposes, highly worthy of imitation.

Purified pit-coal is nothing but that which has been deprived of its oil by the action of fire. This sort of coal burns without smoke, without softening, and without diffusing any strong smell; in a word, it is a true coak; and is, on account of these properties, preferred for fires in rooms.

Another inconvenience, besides the copious dark smoke proceeding from it, which attends the burning of pit-coal, is, that the copious and rapid stream of air requisite to maintain it in combustion, carries before it, and volatilizes, a part of the ashes. But both these inconveniences may be in a great measure remedied by a judicious construction of chimneys; so that the current of air, and whatever matters mix with it, may be

be entirely carried up, and discharged in the air, and no part of it returned and dispersed through the room.

This combustible matter will in France be applied with most advantage for the service of arts and manufactures of all kinds ; in consequence of which wood may be greatly saved for kitchen and room fires, and for building.

C H A P.

C H A P. XXVIII.

Species. V. Of *Petroleum*.

THE name of *petroleum*, or *oil of stone*, has been given to a liquid bitumenous substance, which runs between stones upon beds of rocks, or in various places on the surface of the earth. This oil is of various degrees of levity, smell, consistency, and inflammability. Authors take notice of a great many varieties of it. The lightest, the most transparent, and the most inflammable petroleum, they have distinguished by the name of *naphtha*. *Petroleum*, properly so called, is a liquid bitumen, somewhat thick, and of a deep brown colour: mineral pitch, again, is a black bitumen, thick, scarce liquid, tenacious, and adhesive to the fingers. The following varieties have been described by Wallerius and several other naturalists.

Varieties.

1. White naphtha.
2. Red naphtha.

3. Green

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Varieties.

3. Green or dark naphtha.
4. Petroleum mixed with earth.
5. Petroleum trickling through stones.
6. Petroleum swimming on waters.
7. Mineral pitch, or *maltha*.
8. Pissasphaltus. It is of a middle consistency between that of common petroleum and that of asphaltus or bitumen of Judea.

The several sorts of naphtha are found in Italy, in the Duchy of Modena, and on Mount Chiàro, about twelve leagues from Placentia. Kempfer, in his *Amœnitates Exoticæ*, relates, that great quantities of it are gathered in many places in Persia. Petroleum runs in Sicily, and in many places of Italy; in France, at the village of Gabian, in Languedoc; in Alsace, at Neufchatel in Switzerland; in Scotland, &c. Pissasphaltus and mineral pitch were formerly obtained from Babylon, in the building of the walls of which they had been employed; from Ragusa in Greece, and from the pond of Samosata, the capital of Comagena in Syria. It is at present obtained from the principality of Neufchatel and Wallengin from the Well de la Page, a league from Clermont-Ferrand in Auvergne, and from various other places.

With regard to these several varieties, it is to be observed, that they seem to be all produced from one common origin, and to be but different modifications of the same substance. Most naturalists and chemists ascribe the formation of petrolea to the decomposition of solid bitumens by the action of subterraneous fires. Naphtha, they observe, appears to be the light oil

which is first disengaged by fire: that which follows after it having colour and consistency, forms the several sorts of petroleum: And, lastly, petrolea, united with earthy substances, or altered by acids, acquire the characteristics of mineral pitch or pissasphaltus. The phenomena of the distillation of amber favour this opinion: It affords actually a sort of naphtha, and a petroleum too of a higher or a lighter brown colour, according to the degree of heat employed, and the length of time spent in the operation. Lastly, They observe, that nature often affords all the different sorts of petroleum in the same place, from the lightest naphtha to mineral pitch. Such are the fluid bitumens from Mount Festin, in the Duchy of Modena. Altho' this opinion be very probable, yet other authors think petroleum an oily mineral combination, formed by the sulphuric acid with some fat matters. But even such a combination must still be allowed to originate from organic beings; as fat matters are always formed by those beings.

The chemical properties of petroleum have not yet been examined. We know only that naphtha is very volatile, and so combustible that it takes fire when brought near any burning body; it even appears by its volatility to attract the flame. From brown petroleum there is obtained an acid phlegm, and an oil which at the first resembles naphtha, but acquires a colour as the distillation proceeds. There remains in the retort a thick matter like pissasphaltus, which by greater activity of fire may be rendered dry and brittle like asphaltus, and entirely reduced to a carbonaceous state. Alkalis scarce act upon petroleum: the sulphuric acid colours and thickens it; the nitric acid kindles it in the
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same manner as essential oils: it easily dissolves sulphur; it is coloured by metallic oxides; and it combines with amber, and with the help of heat softens and dissolves a part of it.

The several kinds of petroleum are used for various purposes in the countries in which they abound. Kempfer tells us they are used in Persia, to give light, and burnt in lamps with wicks. They may also be used for common fires. Lehman says, that for this end the naphtha is poured on a few handfuls of earth, and kindled with paper: it takes fire and burns with great activity, but diffuses a smoke in great abundance, which sticks to all bodies that come in its way, and has a very disagreeable smell. Petroleum is likewise thought to make part of the Greek fire. Thick petroleum makes also a very solid and durable mortar. By the decoction of pissasphaltus with water, an oil is obtained, which is used for pitching vessels.

Lastly, Some physicians have prescribed petroleum with success in disorders affecting the muscles, palsy, weakness, &c. by rubbing the skin with it, or exposing it to its smoke. Vanhelmont thought friction with petroleum an excellent cure for frozen limbs, and recommends it as a good preservative against the effects of cold.

[End of the Third Volume of the Original.]

PART THIRD.

The VEGETABLE KINGDOM.

CHAP. I.

Of the Structure of Vegetables.

VEGETABLES are organized beings, confined to the surface of the earth, without sensibility or power of motion. They are known by their appearance, and the conformation of their parts. They are distinguished from minerals, as being capable of receiving nourishment internally, and elaborating the juices to which they owe their growth. They display to our observation phænomena which depend on their organization and are called *functions*; the chief of these is that of reproducing themselves by seeds or *ova* like animals.

Vegetables differ from one another, 1. In size; they are divided into trees, shrubs, herbs, mosses, &c. 2. In

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local situation; some grow in dry grounds, others thrive in a moist soil; some, again, in sand, clay, water, on the surfaces of stones, or on other vegetables, &c. 3. In smell, taste, colour, &c. 4. In duration; plants either live for a number of years, or only for one year, or are produced and die twice a year, &c. 5. In the uses to which they are applicable; they are used either as aliments, or as medicines. A great many of them are made use of in the arts, for dyeing, &c. others for adorning gardens, &c.

Vegetables, considered with respect to the external conformation of their parts, consist of six parts or organs, destined each to a peculiar function: these parts are the root, the stem, the leaf, the flower, the fruit, and the seed. These again differ in different plants, in form, contexture, bulk, number, colour, hardness, taste, &c.

1. The root is concealed in the ground, in water, or in the bark of some other vegetable. It is either tuberos, or fibrous, or bulbous. Its direction is either perpendicular or horizontal. Both its form and consistency are subject to great varieties. Botanists divide the roots of plants into many species; which distinctions they sometimes make use of to determine the specific characters of the plants themselves.

2. The stem proceeds from the root, and supports the other parts of the plant. It is either solid or hollow, ligneous or herbaceous, round, square, triangular, or with two very acute angles, &c. The stem consists of wood and bark. The wood is distinguished into wood properly so called, and sap: the bark consists of the epidermis, the vesicular part or pulp, and the cortical strata or inner rind. The stem divides into

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branches,

branches, the structure of which is precisely the same with its structure. This part, too, is liable to such diversities as enable botanists to establish upon it the distinctive characters of species, and still oftener of varieties.

3. The leaves of vegetables are extremely various: A. in form; they are oval, round, linear, sagittate, hastate, oblong, elliptical, cuneiform, &c.: B. in their position on the stem; they are sessile, petiolate, opposite, alternate, stellate, perfoliate, vaginal, &c.: C. in their margins; they are uniform, dentate, crenate, serrate, repand, undulated, laciniate, truncated: D. in simplicity or composition; compound leaves are formed by the insertion of foliolæ, or smaller leaves; they are then either digitate or conjugate, with either an even or an odd number of leaves: E. in place or situation; they are radical, cauline, or floral: F. in colour, smell, taste, consistency, &c. they seem designed to absorb elastic fluids from the atmosphere, and to pour others into it, according to circumstances.

4. The flowers are those parts which nature has designed to contain the organs of generation, and to preserve them from injury till the fecundation is accomplished; at which time they fall off. A flower consists of two parts; the exterior, designed to cover and protect the interior; the use of which is to re-produce the plant. The former comprehends the calix and the corolla; the calix is exterior, and of a green colour.

Linnaeus divides the calices of plants into seven species; namely, the perianthium, the spatha or sheath, the husk, the involucre, the amentum or catkin, the calyptra or veil, and the volva. The corolla is the coloured part, com-

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monly called the *flower*: it is either a single piece, and monopetalous, or consisting of several pieces, polypetalous. Tournefort's system is founded on the corolla. The pieces of the corolla are called *petals*. The organs inclosed, and often entirely concealed in the corolla, are the *stamina* and *pistils* or *styles*. The *stamina* are the male or fecundating parts; and are almost always more numerous than the *pistils*. They consist of the *filament* and the *anthera*. The *anthera*, placed at the extremity of the *filament*, is a small bag, containing fecundating powder. The *pistil* stands in the middle of the *stamina*; it is sometimes on another flower, or even on another plant: this circumstance has caused some plants to be distinguished into male and female. The *pistil* consists of three parts; the inferior part or *ovarium*, which contains the embryo, and is called in Latin *germen*; the *filament*, which rises out of the *ovarium* or *style*; and its extremity, which is more or less dilated, and is called *stigma*. The sexual system of Linnæus is founded on the number, and the relative positions of the *stamina*, and the *pistils*. M. de Jussieu has formed a system in the insertion of the *stamina*, above or under the *germen*, &c.

5. Flowers are succeeded by fruits. Botanists distinguish fruits into seven species; the capsule; the *siliqua*; the *legumen*; the *conceptaculum*, which becomes dry; fruits having kernels; fruits having pippins and berries, which remain succulent. The purpose of these organs is to inclose the seeds, and to protect them from suffering by the action of external bodies.

6. The seeds of plants differ greatly in form, magnitude, appendices, &c. The seed contains the plumula or small plant, the *radicula*, and the *cotyledons*. There are two of these latter in most vegetables; yet many

families of plants have but one cotyledon. This part is to the grain what the yellow and white of an egg are to the embryo bird; it contains a substance intended for nutriment to the young plant during the germination. Besides, the cotyledons of many seeds contain fleshy and farinaceous bodies, &c.

Vegetables, considered as to their internal structure, contain five species of vessels or organs which exist through all their parts, 1. The common vessels which convey the sap. These are placed in the middle of plants and trees; they rise perpendicularly, but bend laterally, so as to form small vacancies between them, 2. The peculiar vessels which secrete and convey the juices peculiar to each vegetable, oils, resins, gums, &c. These are placed under the bark; they are often dilated into cavities, or reservoirs; they seem to be excretory ducts. 3. The tracheæ, through which the air that vegetables take in from the atmosphere circulates. When a young and green branch is broken, these may be observed, and known from their spiral form, resembling a cork-screw. They are often full of sap. 4. The utricles, which are small vessels containing a secreted juice, and frequently colouring matter. They are placed in the middle of the stem. 5. The vesicular tissue, exhibiting a series of small cells, leading horizontally from the pith, crossing the sap-vessels, filling up the vacuities among them, and spreading over the epidermis, where they form a soft covering like the skins of animals. The vesicular tissue of vegetables seems to correspond to the cellular membrane of animals.

All parts of vegetables consist of an assemblage of these five kinds of vessels; which are, each of them,

them, more or fewer in number, dilated, contracted, &c. On this diversity in point of number and disposition depend the differences in the form and texture of the roots, stems, leaves, &c. of plants.

Malpighi, Grew, and Duhamel, are the three naturalists who have studied the anatomy of vegetables with the greatest success; and their works will be consulted with the greatest advantage, concerning the internal structure of the several parts of vegetable bodies.

C H A P.

C H A P. II.

Of the Natural Philosophy of Vegetables.

ALL these organs of vegetables, of which we have given the above brief account, are designed for the performance of the various motions called *functions*. These functions are,

1. The motion of the fluids, which is a sort of circulation.
2. The alterations or changes produced on those fluids, which are effected in their secretion.
3. The growth of the vegetable and the development of its parts by nutrition.
4. The exhalation of the several fluids elaborated by the organs of vegetables, and the receiving of several principles from the atmosphere by the same organs.
5. The action of air, and the employment of that fluid in the vessels of vegetables.
6. The motion performed by some of their parts.

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7. That sort of sensibility by which they court the contact of bodies that may be useful to them, such as light, &c.

8. Lastly, The several phænomena, by which plants are generated, and species reproduced. Let us consider each of these functions more particularly.

The principal fluid in vegetables, which is called the *sap*, is contained in certain ducts, which are known by the name of *common vessels*. These vessels, situated in the centre of the stem, and under the bark, extend from the root all the way to the leaves and flowers. The sap which they convey is a colourless fluid, more or less insipid in taste, and intended, like the blood of animals, to be separated into different juices for the nourishment and sustenance of the various organs. In spring it flows very copiously, causing the plant to display leaves and flowers. By applying ligatures, and by all the phænomena of vegetation, it has been proved, we think in a satisfactory manner, that the sap ascends from the root through the stem and the branches. We are not so certain whether it be true, as some naturalists have thought, that it descends again towards the root. The existence of those valves, which some botanists have represented as belonging to the common vessels of plants, has not yet been demonstrated; not at least unless we give the name to certain filaments or hairs with which Tournefort and Duhamel have observed their interior sides to be lined. There is a vast difference between this irregular motion and the circulation of the fluids in animals.

The sap being conveyed into the utricles, and thence into the proper vessels, is there elaborated in a peculiar manner. By this elaboration it is wrought into different fluids, saccharine, oily, or mucilaginous, which

which are discharged by an organic excretion; and of which the evacuation seems to be an advantage to the vegetable, as it does not appear to suffer even from a considerable loss of these matters. This alteration of the fluids, which may be distinctly observed as it takes place in several of the organs, in the nectarium, for instance, at the extremity of the pistil, in the pulp of fruits, at the base of the calices, and of many of the leaves, is entirely effected by a function similar to that which in animals bears the name of *secretion*. Guetard has carried this analogy so far as to describe glands of various forms, at the bases of the leaves of fruit-trees, and towards the inner extremity of the petals of certain flowers. This secretion separates the odorous principle, the colouring matter, the combustible substance, &c. but it differs from animal secretion, as animal secretion is entirely owing to the organization of the glands which elaborate the animal fluids; whereas in vegetables, the juices conveyed through the common vessels are in the proper vessels more exposed to the contact of air and light and the action of heat; and their situation renders them liable to pass, by the operation of these agents, through a process of fermentation, by which only they can be altered.

The sap in the cavities of the utricles and the vesicular tissue, becomes thick, and acquires more or less consistency. In consequence of this alteration, it adheres to the sides of the fibres, and incorporates with them gradually, so as to increase their dimensions. Such is the mechanism by which vegetables are nourished and grow, and unfold their parts. It bears a great resemblance to the nutrition of animals. The vesicular tissue of vegetables and the cellular membrane of animals, are formed with a similar structure, and intended to

serve

serve similar purposes. They pass in the same manner through all the organs of the bodies to which they respectively belong; they establish a direct communication among these organs; and both may be said to be the seats of nutrition.

Philosophical botanists have long been convinced, that plants exhale effluvia from the surfaces, which are diffused through the air. The odorate spirit of leaves and flowers forms round vegetables an atmosphere which affects the senses in a lively manner; and which, as has been observed with regard to the fraxinella, the contact of a burning body will sometimes set on fire. This effluvia appears to be an inflammable gas of a peculiar nature. Mankind have also learned from fatal experience, that some vegetables exhale vapours, noxious to such animals as approach them. The walnut, the yew, and many other trees, natives of warm climates, are of this kind.

M. Ingenhoufz has discovered by experiment, that the leaves of all plants, when exposed to the sun and to light, pour into the atmosphere an invisible fluid, which is vital air of the same qualities with that obtained from oxide of manganese, mercury, &c. But in the shade they no longer exert such a property; instead of vital air, they give out carbonic acid gas, when deprived of the contact of light. This valuable discovery, which was first communicated to the world by Dr Priestley, shows vegetables to possess a property that was not before attributed to them, and to be capable of purifying and renovating the air, by pouring into it a portion of that vivifying fluid which is constantly consumed by combustion, respiration, &c. But if vegetables are continually diffusing vaporous fluids through the atmosphere, produced by the last processes
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of vegetation, they likewise absorb several of the principles of the atmosphere. The experiments of Bonnet show, that the under surface of the leaves absorbs moisture from the dew. Dr Priestley has proved, by his researches, that vegetables absorb the gaseous residues of combustion and respiration; for vegetation is more speedy and vigorous in air altered by these phenomena. Exhalation and inhalation are therefore much more considerable and important phenomena of the vegetable kingdom than they were known to be before the modern discoveries. It even appears, that the water absorbed by the under part of the leaves is decomposed by their organs, its hydrogenous gas absorbed, and its oxigene converted into the vital air which is disengaged from the upper surfaces of the leaves. The rays of the sun contribute greatly to this decomposition; for it does not take place in the shade. The water being then not decomposed, but entirely absorbed, renders the plants white, insipid, soft, and in a word *ætiolated*; and in such cases, much less colouring, combustible, or oily matter, is formed than when the plant is exposed to the action of light.

The gases absorbed by vegetables are conveyed thro' all their organs by vessels known under the name of *tracheæ*, which in their use and structure bear a resemblance to those of insects and worms. But the conveyance of this fluid is not the only purpose for which these tracheæ are intended. They are observed to be filled with sap in the season when that fluid flows in greatest abundance; a circumstance which distinguishes them widely from those organs of respiration which belong to so great a number of animals, and are so essentially necessary. From the theory of respiration which we have laid down in the history of air, it is easy to explain

explain why vegetables possess not free heat in a degree of temperature superior to that of the atmosphere.

Several parts of vegetables have, no doubt, an internal principle of motion. In some plants this motion is so considerable as to be observable by the eye. Such is the motion of the sensitive plant, of the stamina of the Indian fig, of pellitory, &c. This motion seems to correspond to that function of animal organs which is called *irritability*; for it is effected by the action of a stimulus, and by peculiar organs, which are by some botanists compared to the muscular fibres.

Can we deny plants to possess a sort of sensibility, when we see them turn their leaves and flowers towards the sun; when we observe, that, if inclosed in boxes of wood, with glass on one side, or perforated with an open hole, or simply thinner on that side than on the other, they constantly turn towards the transparent body, or the aperture through which light is permitted to enter, or the side which, being thinner, is nearer to that fluid than the other? Or, is this appearance of sensibility rather to be considered as an effect of the power of affinity, of the tendency of vegetables to combine with light? It has been fully proved, that, either by percussion or combination, this substance produces in plants the properties of colour, taste, and combustibility; in the shade even the tallest plants are white, insipid, aqueous, and destitute of any inflammable principle: but, again, vegetables exposed to the rays of the sun, in the torrid climates of the south, are very high-coloured, contain bitter and resinous parts, and are very combustible. However strong this affinity be allowed to be, yet it is hard to imagine how it could excite such a motion in the branches and leaves of vegetables.

getables. We must therefore grant them a peculiar sensation, a sort of feeling very different indeed from that of animals, by which they are enabled to distinguish and prefer such situations as are most exposed to light.

The methods which nature uses for the reproduction of species of vegetables are strongly analogous to those by which the generations of animals are perpetuated. The greatest number of the species of plants are propagated by sexual coition. The labours of the celebrated Linnæus have discovered a striking resemblance between the organs designed for this purpose in these two classes of organic beings. The stamina of plants correspond to the genital parts of male animals, and the pistils consists of three parts, which bear an equal resemblance to the same organs of female animals. The embryo is developed by the action of the fecundating powder, without which a new individual could not be produced from it; agreeably to what is daily observed of birds. But besides this analogy, which it would be needless to trace farther, as vegetables are of a much simpler structure than animals, and their parts consist all of the same organs, any of them is capable of producing a new individual similar to that to which it belonged. This is the reason of the reproduction of plants by means of scions or slips, as well as of the alteration of their fluids by grafting, whether natural or artificial. Here, therefore, is another analogy between vegetables and that class of animals which are reproduced by division into pieces, as polypi, crustaceous insects, certain worms, &c.

All these functions of vegetables, which bear so striking an analogy to those of animals, are liable to alterations, by which the vegetable is brought into a diseased state.

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state. These diseases to which plants are liable, depend commonly either on superfluity or defect of sap, as well as on the bad qualities which the sap may happen to acquire; and they bear therefore no small resemblance to those with which animals are affected. Their causes, symptoms, and cure, come under the general principles of medicine; and form a branch of agricultural knowledge, in which it must be confessed little progress has yet been made; but which may be greatly advanced by following the directions of some celebrated modern writers on the subject.

VOL. II.

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C H A P.

CHAP. III.

Of Juices and Extracts.

THE fluids contained in vegetables are of two kinds the common and the proper juices. The first of these constitute the sap, which is found in all plants. This fluid seems to perform the same functions in vegetable which the blood does in animal bodies. It is contained in the common vessels: It runs naturally from their surface; but may be extracted in greater abundance by incision. The sap is not an aqueous fluid but contains salts, extracts, and mucilages. When a certain quantity of it is wanted, in order to an examination of its properties, or for medical uses, the plant is brayed in a mortar, and squeezed through a linen cloth: if the plant does not readily yield its juice, it is put into a press.

Succulent vegetables give out their juice by simple expression. Those whose juices are viscid, or not very copious, must be treated with water to swell and dilute them; such are borage and the dry aromatic plants. This fluid, when extracted by the force of pressure,

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found to contain a portion of the solids of the vegetable, which were bruised with the pestle: it must then be purified. Juices of plants are purified, 1. Simply by rest, or by filtration, when they are very fluid: in this way, for instance, are the juices of purslain and the house-leek purified. 2. By the white of eggs, which collects the impure parts by coagulation; it is used with borage, nettles, &c. 3. By the simple application of heat, which coagulates and precipitates the parenchyma. M. Baumé recommends this as the best way for purifying those vegetable juices which contain volatile principles, such as that of cochlearia, creffes, &c. The phial containing the juice is immersed in boiling water, care having been taken to cover it with a piece of paper perforated with a hole; when the juice becomes pure it is taken out; it is then immersed in cold water, and the juice filtrated. 4. By alcohol, which coagulates the feculent part. 5. By vegetable acids, which the London pharmacopœia prescribes for the juices of cruciform plants.

There are matters dissolved in the juices of plants which, when separated from the aqueous vehicle, form what is called in pharmacy the *extract*. These matters are distinguished into three species, mucilaginous, saponaceous, and gum-resinous extracts.

Those are called *mucilaginous extracts* which dissolve easily in water, are scarce soluble in alcohol, and undergo spirituous fermentation; such is the rob of the gooseberry, which is prepared by evaporating the juice.

Saponaceous extracts dissolve in water, are partly soluble in alcohol, and rather mould than pass into a state of spirituous fermentation. Such is the juice of bo-

rage when reduced to an extract. These are extracts properly so called.

Gum-resins are soluble both in water and in alcohol. They are inflammable, as containing a resinous principle, and are not liable to suffer any alteration from air. The concentrated juice of wild cucumber, called *elaterium*, is of this sort. Incisions are made in the fruit of this plant; and the juice squeezed out, suffered to clarify of itself, and evaporated to dryness on a water-bath.

These three different sorts of extracts are prepared in the great way for commerce by the evaporation of the juice of various plants. Of these, among others, are,

1. The juice of acacia; which is prepared in Egypt by pounding the fruit of that tree, pressing out the juice, and evaporating it by the sun: the juice of acacia from Germany is prepared from the juice of flocs by a similar process.

2. That of hypocistis, which is prepared like the above, from the fruits of this parasitical plant.

3. Opium, a medicine of great importance, the nature of which should be very well known. It is extracted from the white poppy in Persia, &c. There flows out by incisions made in the green capsules of that plant, a white juice, which is dried into brown tears; this is the true opium. The opium which is commonly sold is prepared by first soaking the capsules in water, and then squeezing them; this juice is dried, and formed into flat circular cakes, covered with leaves, and mixed with a good deal of impurities. To purify it, it is dissolved by the help of heat, with as small a quantity of water as possible; the liquor is filtered or strained by strong pressure, and evaporated on a *balneum mariae*.

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This is the extract of opium. This substance contains a saponaceous extract, a resin, a solid essential oil, an odorous principle, which is poisonous and narcotic, an essential salt, and a glutinous matter. As the odorous, poisonous, and narcotic principle is often noxious, attempts have been made to obtain the extract of opium without that principle. M. Baumé, who has examined this medicine with much care, volatilized that principle, together with the essential oil, and in consequence of that separated the resin by digestion, for six months. Bucquet has discovered, that this extract may be obtained in such a state as to be sedative, and not narcotic, by dissolving opium in cold water, and evaporating the solution in a *balneum mariæ*. Lorry, who has made some very valuable experiments on this matter, has discovered, that fermented opium affords by distillation a sedative water which has no poisonous qualities, and has prescribed it with great success. He observes, that the odorous principle of this medicine cannot be destroyed by any process.

To obtain the extracts of dry ligneous plants, we must employ maceration, infusion, or decoction in water, according to the particular state and nature of the matter from which the extract is desired; maceration is often sufficient. Odorous plants can only be treated by infusion. Decoction carries off too much of their substance, and separates the resinous part: it forms an highly concentrated thick fluid, which becomes turbid by cooling. Infusion will be sufficient in any case. Such is the opinion of the greatest chemists and the most celebrated physicians.

By water various products can be extracted from several plants. Thus juniper-berries afford with water a mucilaginous extract; quinquina affords a saponaceous

ceous extract, which is obtained in small transparent scales of a saline appearance, if the solution be evaporated in broad flat vessels; rhubarb affords in the same manner a gum-resinous substance.

The chemical extract, properly so called, or the saponaceous extract, seems to be a compound of oil with fixed vegetable alkali. The extracts prepared in pharmacy are far from being all of the same nature; they are mixed with mucilage, essential salt, saccharine juice, and resin. For this reason, Rouelle, with a view to throw new light on this part of medical chemistry, has distinguished them, as above mentioned, into three genera. But the pure extract, reckoned among the immediate principles of vegetables, is to be considered as a saponaceous compound possessed of peculiar properties.

There are extracts prepared in the great way for commerce by water. Such are,

1. The juice of liquorice, which is yellow by the first infusion, and black by a powerful decoction. The black juice is burnt, and actually contains coal. It is purified by melting it in water, filtering and evaporating the solution, which is rendered aromatic by the addition of essential oil, of anniseed, cinnamon, &c.

2. The cachou, which is obtained in the East Indies from an infusion of the seed of a certain palm-tree, called the *areca*. This solution is evaporated, and the matter obtained formed into broad cakes. The cachou is purified for medical purposes by solution in water and evaporation. It is seasoned with aromatic like liquorice juice.

Among the extracts which are prepared for medical purposes, Rouelle has taken particular notice of those

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mixed with resin, by the name of *extracto-resinous*, or *resino-extractive matter*.

Extracta-resinous matter does not burn till after it be dried: it seems to contain more extract, properly so called, than resin. *Resino-extractive matter* burns much better than the former: it seems to contain a greater proportion of resin than of the extractive matter. This distinction proves these two species to be nothing but mixtures of extract in various proportions with a resinous principle. They are not, therefore, extracts properly so called; and the name can be with propriety applied only to the saponaceous matter; which is therefore the substance whose properties we ought to examine.

The pure extract differs from those above-mentioned. Taking all its properties together, we may consider it as a dry solid substance, of a brown red colour, transparent, not capable of burning by itself, but which exhales a good deal of smoke, and is found to contain more or less essential salt. Its taste is almost always bitter, it affords by distillation an insipid phlegm; exposed to a moderate fire, the phlegm by degrees takes a colour, and becomes of an alkaline nature, which is observed of elaterium, the extract of borage, &c. The ammoniac of the product is formed by the heat: there passes, next, a little empyreumatic oil; the coal is light, contains potash, and almost always neutral salts. The extract, when exposed to the air, acquires a kind of moulding all over its surface, and attracts moisture; and the salts mixed with it crystallize and separate from the extractive part. They are often entirely altered and decomposed on this occasion. It dissolves in water, and is then like a strong infusion. Acids decompose this solution like soaps. Metallic solutions likewise precipitate it; and the substances are, on this

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occasion,

occasion, mutually decomposed. The chemical properties of the extract have not been farther examined: on account of these which it is known to possess, it is, with good reason, considered as a kind of soap.

Extracts are employed in medicine as aperitives, diffusives, diuretics, stomachics, and almost always with great success.

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C H A P. IV.

Of the essential Salts of Vegetables; and of those in particular which are analagous to Mineral Salts.

THE saline substances held in solution in the juices of plants, or in water in which they have been infused, are called their *essential salts*. They are extracted by suffering these fluids to cool, after they have been evaporated to the consistency of a syrup. As these salts are impregnated with extracts and fat matters, they need to be purified with lime and the white of eggs. When the salts are acid, lime must not be used, as it would neutralize them, but pure white clay in powder. After this first extraction they are still very impure. They are dissolved in distilled water, and repeatedly crystallized till they become white. This process can be employed only on those essential salts of vegetables which are crystallizable; but there have been some vegetable salts discovered which are not crystallizable, and which, on account of their mixture or combination with other principles, cannot be extracted by such a simple process. In giving an account of the salts contained in
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vegetables, or at least obtained from them, we shall distinguish them into the following six genera.

The first genus comprehends all such vegetable salts as are analogous to those with which we are acquainted in the mineral kingdom.

The second consists of the pure acid salts of plants.

In the third we shall rank acid salts combined with a certain quantity of potash, under the generic name of *acidulæ*.

To the fourth genus we may refer such as are formed by the action of the nitric acid on some vegetable matter.

The fifth may contain such as owe their formation to heat.

Lastly, Under the sixth we include vegetable acids produced by a particular fermentation.

First Genus of Vegetable Salts. Salts analogous to those of the Mineral Kingdom.

THE first genus of the essential salts of vegetables comprehends neutral salts extracted from their juices by evaporation, which are analogous to those of the mineral kingdom. The principal species of those salts are, 1. Fixed alkalis in combination with carbonic acid, which are obtained from almost all plants, by macerating them in acids, as has been shown by Margraaff and Rouelle the younger; potash is most commonly obtained; soda exists in some marine plants. 2. Sulphate of potash, in millefoil, in old borage, in astringent and aromatic plants, in spurge flax, and in the mark of olives. 3. Sulphate of soda, from tamarisk, and from

rotten

rotten wood. 4. Nitre, from borage, turnsole, tobacco, &c. 5. Muriate of potash, and muriate of soda, from marine plants. 6. Sulphate of lime, discovered by Model in rhubarb. The existence of the last salt is doubtful; for Scheele suspects that what Model took for sulphate of lime was only calcareous oxalate, or salt of forrel.

By an accurate analysis of a greater number of plants, many other salts might no doubt be found in vegetables, resembling mineral salts. It was also thought that ammoniacal carbonate existed ready formed in some cruciform plants; because those plants, when distilled, afforded by the first impression of the heat a phlegm, in which there was a little of this salt suspended. The ancient chemists, on this account, called those plants *animal plants*. But Rouelle the younger has shown, that the salt is not ready formed in the plant, but is produced in consequence of the reaction of the principles of the plant occasioned by heat. M. Baumé has represented this volatile principle of cruciform plants, as being nothing but sulphur. The ammoniac obtained from those plants has been fully proved by M. Berthollet, to proceed from the combination of the hydrogenous part of the oil with the azote contained in the vegetable.

Naturalists have been of different opinions concerning the mineral salts found in plants. Some think the salts to be conveyed from the earth into the vegetable by water, without alteration. Others think them to be formed by the act of vegetation. One thing certain is, that two very different plants, such as borage and millefoil, growing on the same soil, afford each its peculiar acid; borage, nitre,

and millefoil, sulphate of potash. This doubtful question might be determined by a single experiment; of which much has been said, but which has never been performed with sufficient exactness. The experiment is, to raise from a previously lixiviated earth plants affording a kind of salt, like nitre, and to water them with water impregnated with muriate of soda, or some other salt. If they should be still found to afford nitre, and not muriate of soda, it might be inferred, that salt does not pass from the earth into the plant unaltered, but that the proper salt is formed in the plant by the functions of vegetation. Whatever may be the result of this experiment, it will be proved, that a number of the salts which we examined in the mineral kingdom are immediately formed in vegetables.

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C H A P. V.

Of the second Genus of Essential Salts, or of the pure Acids of Vegetables.

IN the second genus of essential vegetable salts, we rank those acids which are entirely formed in plants, and are extracted from them pure by very simple processes. There are five acids of this genus, the citric, the gallic, the malic, and the benzoic.

§ 1. *Of the Citric Acid.*

WE give the name of *citric acid* to the pure acid which Scheele obtained from lemon juice.

Chemists formerly, without attending to the peculiar characteristics of this acid juice, compared it to that of tartar; and at that period all vegetable acids were thought to be of the same nature. Attempts have been

been made to concentrate and purify the acid juice of the lemon and the orange, in order to preserve them for long voyages. The juice of the former of these fruits has such an acid taste, and produces such an effectual alteration on blue colours, that there can be no doubt entertained concerning its nature, M. de Morveau has found the specific gravity of this juice to be to that of distilled water as 1,860 to 1.

When this juice is kept for some time, it acquires a disagreeable taste, and is covered over with a mouldiness: this alteration is owing to its containing a considerable proportion of mucilage, of which chemists have endeavoured to purify it. Before means were found out by which that might be accomplished, it was preserved in glass bottles, and covered with oil. Some people proposed to put sand into the vessels; others added a mineral acid; either of these processes altered the nature of the juice. The first was superior to the other, but even with it, the juice, in the space of a few days, contracted a tart, oily, and disagreeable taste. M. Georgius in the year 1774, published, among the Acts of the Academy of Stockholm, a process for concentrating the acid juice of citrons, and rendering it unalterable. He directs this juice to be kept for some time in the cellar, in inverted bottles, in order to separate from it a part of the mucilage, and to expose it to a cold 3 or 4 degrees under 0 in Reamur's thermometer; the aqueous part freezes, carrying with it, as would appear, a portion of the mucilaginous matter: care must be taken, as the ice forms, to separate the liquid from it; and the congelation must be carried on till the ice become acid. M. Georgius has found, that when the juice is reduced to an eighth part of its bulk, and is eight times as strong as before, a drachm of citron juice,

juice, concentrated by congelation, will saturate thirty-six grains of potash, which would require to saturate it an ounce of the same juice before concentration. This acid, thus concentrated, may be employed for many economical purposes. Dry lemonade is prepared by mixing it with sugar refined and reduced to powder, in the proportion of one part to six.

Citron, or lemon juice, if exposed soon after its preparation to an atmosphere above the temperature of 15° of Reaumur, deposits a white semi-transparent, mucilaginous matter, of a gelatinous consistency: this juice, when decanted and filtered, becomes less liable to alteration than before. The mucilaginous matter, when dried, does not dissolve in boiling water: when treated with the acid of nitre, it affords azotic gas, and is converted into oxalic acid: this is not a gummy mucilage, but bears an analogy to the vegetable gluten, of which we spoke in the article farina.

M. Dubuiffon has preserved citron juice by a process directly opposite to that of M. Georgius. On evaporating this juice by a moderate heat long continued, the mucilage becomes thick, and separates in the form of a crust and glutinous flakes; the acid liquid is concentrated, and may be long kept in well stopped bottles without being liable to alteration. M. Dubuiffon has observed, that the contact of the air which remains between the stopper and the surface of this acid liquor concentrated by evaporation, is sufficient to separate in a few weeks flakes of a white substance, which he thinks to be glutinous, and which collecting on the surface, form there an elastic consistent body. The acid is not sensibly altered during this separation.

These are the several processes which were proposed
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and used, before Scheele's time, for purifying and preserving citron juice. From them it appears indeed, that this acid has engaged the attention of chemists; but it was prepared only for the purposes of pharmacy; and so fully was every one persuaded that its nature was the same with that of the acid of tartar, that no doubt was ever suggested of that being the case. Stahl had asserted, that lemon-juice, when saturated with the lobster stone or with chalk, acquired the nature of vinegar. Several chemists had attempted to combine it with alkalis, without obtaining permanent crystals from the combination, on account no doubt of the mucilage so plentifully mixed with it. M. de Morveau, however, informs us, that by saturating lemon-juice with carbonate of potash, exposing the solution to the air, and filtering it several times, he obtained from it a salt crystallized in small opaque grains not liable to deliquesce.

Scheele, in Crel's Journal, in the year 1784, gave a process for obtaining the acid of lemon very pure, separated from the mucilage and the extractive matter by which it is altered in the juice as pressed from the fruit, and in a concrete form. He first employed alcohol to separate the mucilage by coagulation, and did not succeed; the liquor, when inspissated, filtered, and evaporated, afforded no crystals. He tried the process which he had several years before discovered for purifying the acid of tartar, and obtained the acid of lemon, pure and concreted. The process is as follows: Saturate boiling lemon-juice with pulverized chalk. The acid forms with the lime a salt that is scarce soluble, and the mucilaginous and extractive substances remain dissolved in the supernatant liquor; the precipitate is to be washed with lukewarm water, till it ceases to deepen

deepen in colour; it dissolves nearly as well as sulphate of lime: it is then treated with as much sulphuric acid as is requisite to saturate the chalk, diluted in ten parts of water; and the mixture is now boiled for a few minutes. Afterwards it must be cooled and filtered; the sulphate of lime remains on the filter; and the liquor affords by evaporation a concrete crystallized acid. In this operation, it is better, as Scheele has remarked, to use an excess of sulphuric acid, than to leave a little lime not saturated: as this would prevent the citric acid from crystallizing; whereas, when there is an excess of sulphuric acid, it remains in the mother-water.

The citric acid thus prepared is very pure and highly concentrated: its taste is strongly acid; it reddens all blue vegetable colours that are susceptible of such a change. Fire decomposes it, converting it into acidulous phlegm, gaseous carbonic acid, and carbonated hydrogenous gas: there remains in the retort a little coal: air effects no alteration on its crystals. It dissolves easily enough in water. The solution is decomposed by an actual putrefaction, which indeed takes place but very slowly. With earths and alkalis it forms citrates of aluminous earth, barytes, magnesia, lime, potash, soda, and ammoniac; the properties of which have not yet been examined, though they are known to differ from all other neutral salts. The nitric acid does not convert this, like several other vegetable acids, into oxalic acid: this appears indeed to be one of the most powerful of vegetable acids. It acts with the help of water on various metallic substances, chiefly on zinc, iron, copper, &c.

Bergman has represented its affinities in the following order; lime, barytes, magnesia, potash, soda,

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ammoniac. M. de Bressley of Dijon has an account of its affinities somewhat different from this. According to him, barytes holds the first place, lime the second, and magnesia the third; the alkalis follow after these. It appears from the researches of both, that this acid prefers the three alkaline earths to the alkalis themselves.

The uses of the acid of lemon are various. With water and sugar it composes a very pleasant drink, known by the name of *lemonade*. It is used in medicine as cooling, temperating, antiseptic, antiscorbutic, diuretic; it is especially efficacious in correcting the acridity of the bile. It is sometimes applied as a gentle escharotic to scorbutic ulcers, eruptions of the itch, and spots on the skin. When concentrated by the process of M. Georgius, or that of M. Dubuifson, it may be put up for long voyages by sea; and it is found of great utility on such occasions.

§ II. Of the Gallic Acid.

WE give the name of *gallic acid* to that which is extracted from the nut-gall which grows on oak in consequence of the puncture of an insect. This acid is generally found, either in a greater or a smaller quantity, in all four or astringent vegetable substances. Such are oak, ash, willow, and the barks of these trees, quinquina, fimarouba, pomegranate, sumac, tormentillo, the cypress nut, the stalk and leaves of the marsh iris, of the strawberry shrub, of the water lily, &c.

Chemistry formerly distinguished this matter by the name

name of the *astringent principle*: and all that they knew of it was, that it possessed exclusively the property by which its character was very distinctly marked, of producing black precipitates in solutions of iron in acids, and thus making ink. Messrs Macquer, Monnet, Lewis, Cartheuser, and Goanetti, sought to determine by experiments, in what manner this principle acts upon the metal. M. Monnet remarked, that nut-gall and astringent vegetable juices acted immediately on iron, and gave it a black colour. M. Gioannetti observed, that the atramentarious precipitate or feculum was not subject to the attraction of the magnet, and that iron therefore did not exist in the precipitate in a metallic state, as had been before thought. These observations might lead to the conclusion, that the astringent principle of nut-gall must be an acid, or at least performed the part of an acid in chemical operations. The Academicians of Dijon were, however, the first after these writers, who distinguished, in their experiments, the astringent principle to be an acid. These philosophers have shown, 1. That the products of distilled nut-gall become black with the solution of sulphate of iron. 2. That an ounce of this substance communicates to cold water a tincture, from which $3\frac{1}{2}$ drachms of extract are obtained by evaporation. 3. That this infusion reddens turnsol and blue paper. 4. That the same principle is soluble in oils, alcohol, and æther. 5. That acids dissolve without altering it, and without depriving it of the property of producing a black precipitate of iron. 6. That its solution in water precipitates alkaline sulphures. 7. That it entirely decomposes all solutions of metals, and communicates a colour to the oxides by combining with them. 8. Lastly, That it directly dissolves iron, and precipitates

precipitates silver and gold, after separating them from their solvents.

Such are the important facts concerning this substance, which have been communicated to the world by the Academicians of Dijon. Several of them had indeed been before observed by different chemists, but none had before ascertained the acidity of the principle.

Since they communicated these observations to the world, Scheele has not only observed, that all four, astringent plants exhibit marks of acidity, but has discovered and described a process for obtaining this vegetable acid pure and crystallized.

Upon a pound of nut-gall in powder, pour six pounds of distilled water; leave this mixture to macerate for the space of fifteen days, in the temperature of from 16 to 20 degrees; then filtrate the liquor, and put it in a stone pot, or a large capsule of glass; suffer it to evaporate slowly in the air; a mouldiness, and a thick and seemingly glutinous pellicle is then formed upon it: mucilaginous flakes are first precipitated in great abundance; the solution has no longer a very astringent taste, but is more sensibly acid than before. After it has been two or three months exposed to the air, there is observed on the sides of the vessels, and adhering to them, a brown plate, covered with granulated crystals, sparkling, and of a yellowish grey colour: the same crystals exist likewise in great abundance on the under side of the thick pellicle which covers the liquor: the liquor must now be decanted off; and hot alcohol is poured on the flaky sediment, the pellicle, and the crystalline crust: this solvent takes up all the crystallized salt, but affects not the mucilage. This spirituous solution is then evaporated, and the gallic acid

cid is obtained from it pure, in small granulated crystals, of a grey colour, inclining a little to yellow, and brilliant.

The gallic acid thus purified has a taste somewhat sour and astringent. It produces in solutions of sulphate, and of other salts, of iron a very fine and brilliant black precipitate: it gives a high red colour to the tincture of turnsol; when heated in contact with air, it swells and kindles, diffusing an agreeable enough smell, and leaves a coal, the incineration of which is very difficult: when distilled by a moderate fire, a part of it is dissolved in the water of its crystals, and ascends in that state; another part is sublimed, without being decomposed, in small silky crystals; a strong fire separates from it some drops of oil, carbonic acid gas, and carbonated hydrogenous gas. Nut-gall, when distilled entire, affords a small portion of concrete salt, resembling the sublimated gallic acid.

The gallic acid requires 24 parts of cold water to dissolve it; of boiling water only three parts. Repeated solution and crystallization do not whiten it in a sensible manner. Alcohol dissolves it much more efficaciously: four parts of this liquid, when cold, are sufficient to dissolve one of gallic acid; when boiling, it dissolves a quantity of the acid equal to itself in weight.

This acid disengages the carbonic acid from earthy and alkaline bases, when its action is assisted by heat.

With barytes, magnesia, and lime, it forms salts soluble in water, and especially when there is an excess of the base. Potash, soda, and ammoniac, combine very readily with it, forming *gallates*, the properties

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of

of which are hitherto unknown. The nitric converts the gallic into oxalic acid.

The gallic acid precipitates gold in a brown powder, and causes a part of the metal to appear on the surface of its solution in a brilliant metallic pellicle. In the solution of silver it produces a brown precipitate; and soon after the precipitation, a plate of reduced silver appears on the surface of the liquor. From mercury it produces an orange yellow precipitate; from copper a brown precipitate; from iron a beautiful glittering black precipitate; from bismuth a citron yellow precipitate. Solutions of platina, zinc, tin, cobalt, and manganese, suffer no alteration from this acid.

Such are the properties which Scheele allows to the gallic acid prepared by his process. They are sufficient to intitle it to the character of a peculiar acid, distinct from all others. Its intimate nature, and the proportion of its principles, have not yet been ascertained. M. de Morveau obtained from it a resin which he thinks to be the acidifiable base; by the union of which with oxigene the acid is formed.

The use of nut-gall for dyeing black is well enough known: we shall only add to what we have already said of it in the article of iron, that when the pure gallic acid is used in the preparation of ink, the ink is very beautiful and very black, and remains long unaltered.

§ III. *Of the Malic Acid, or the Acid of Apples.*

WE give the name of *malic acid* to a peculiar vegetable acid which Scheele extracted from the juice of various fruits, and of which he found apples to contain a considerable quantity.

This acid is obtained by squeezing the juice from four apples, saturating it with potash, and mixing the liquor with a solution of acetite or sugar of lead. A double decomposition is thus effected; the acetous acid combines with the potash, and the malic with the oxide of lead; the malated lead is precipitated; that precipitate is washed; and, on its being treated with sulphuric acid, sulphate of lead is produced, and the malic acid swims above. A sufficient quantity of sulphuric acid must be poured in to dissolve all the malate of lead; which, when it takes place, will be known from the taste of the supernatant liquor.

The following are the properties of this acid. It cannot be obtained in a concrete form; with the three alkalis it forms deliquescent neutral salts; with lime it produces a salt that affords small irregular crystals, soluble in boiling water, in vinegar, and in the malic acid itself; with aluminous earth a salt that is scarce soluble; with magnesia, a deliquescent salt. It dissolves iron, and the solution is brown and not susceptible of crystallization; it dissolves zinc readily, and produces with it a salt in very beautiful crystals: the nitric acid changes it into oxalic acid; it precipitates nitrate of mercury, lead, silver, and gold, in a metallic state: calcareous malate decomposes ammoniacal citrate, forming in consequence

sequence of the decomposition calcareous citrate; not soluble in boiling water or in vegetable acids. The solution of calcareous malate in water is precipitated by alcohol; lastly, the malic acid is speedily destroyed by fire, which changes it into carbonic acid: the carbonic acid thus formed, saturates in part the bases of the malates decomposed by heat. Such are the properties which form the peculiar character of this acid.

Scheele found it almost pure, or mixed with a little citric acid, in the juice of apples, of the barberry, of alder twigs, of the floe thorn, of the forb tree, and of the plum tree; in gooseberries, cherries, strawberries, rasp-berries, &c. Lastly, He obtained it from sugar by the nitric acid; and M. de Morveau remarks, that the malic is discovered before the oxalic.

When four fruits contain both citric and malic acid, the following is Scheele's process for separating them, in order to obtain the latter pure. The juice of gooseberries saturated with chalk affords calcareous citrate, which, being insoluble, is precipitated; the supernatant liquor holds in solution the calcareous malate, which is separated by alcohol; but as it is still in union with a mucilage, Scheele has had recourse to another means for obtaining it pure. He evaporated the juice of gooseberries to the consistency of syrup; upon this syrup he poured alcohol, which dissolved the acids without affecting the mucilage; he then filtrated the solution to separate the mucilage; after the filtration of the liquor, he evaporated the alcohol; the acids he saturated with chalk. The citric acid, uniting with the chalk, was, of consequence, deposited in calcareous citrate; and the calcareous malate remained in solution.

A new addition of alcohol precipitated it from the liquor; and Scheele then obtained the malic acid by dissolving this salt in water, precipitating the solution by acetite of lead, and decomposing the malate of lead by the sulphuric acid; the malic acid was then found separate in the supernatant liquor.

§ IV. Of the Benzoic Acid, or the Acid of Benzoin,

SINCE the days of Blaise de Vigenere, who wrote in the beginning of the last century, benzoin has been known to afford, by distillation, an acid salt crystallized in strong smelling needles, of an acrid taste, which in pharmacy are called *flowers of benzoin*. Chemists formerly thought this to be a particular modification of a mineral acid; but its distinctive properties are now so well known, that we can no longer doubt of its being a peculiar vegetable acid.

This acid is found to exist in benzoin, balm of Peru and Tolu, storax, liquidambar, and vanilla around which it is crystallized. Scheele has found it likewise in the sugar of milk and the extract of urine. It will be shown under the article of Benzoin, that the simple process which was formerly employed to obtain it, consisted in sublimation by a moderate fire. Geoffroy discovered in the year 1738, that it might be extracted by water, and that the saline substance was fully formed as it existed in benzoin; by the same process I extracted it from Peruvian balm, storax, and the husks of vanilla. But this process affords only a small quantity; for the resin of benzoin, not mixing with the water, covers and preserves a great part of the acid salt.

Scheele,

Scheele, in the year 1776, gave, in the *Memoirs of Stockholm*, some important observations on the benzoic acid: from 96 parts of benzoin he obtained, by sublimation, between 9 and 10 parts of this sublimated salt, which was very far from what Spielman asserted that he obtained,—namely, a fourth part of the benzoin submitted to distillation: it appears that the chemist of *Strasbourg* had taken acid of benzoin mixed with empyreumatic oil for pure acid. Scheele, having reduced benzoin to powder and mixed it with chalk, boiled upon it a quantity of water, and then filtrated the liquor, which afforded no salt by cooling: sulphuric acid, poured into this liquor, separated the benzoic acid in powder, and showed that acid to have been united with a base of chalk, with which it formed a neutral salt soluble in water: the quantity of concrete acid, however, precipitated by this process was not more considerable than that which is obtained by simple lixiviation. Scheele thought that a greater quantity might be obtained by employing a matter capable of acting on the resin, and facilitating the separation of the salt. Potash did not serve his purpose; the resin again collected on the surface of the liquor in a thick tenacious oil, on which account he could not expect the acid to be entirely separated. With quicklime he was more successful: According to him it is to be applied in the following manner. Take four ounces of quicklime; flake it with 12 ounces of water; add eight pounds more when the ebullition ceases; mix six ounces of this water with a pound of benzoin in powder; these substances need to be well stirred, in order that they may mix properly; pour in by degrees the remaining part of the lime-water; when the lime-water is thus gradually poured in, it hinders the benzoin from

collecting into a mass: this liquor must next be heated for half an hour by a moderate fire, and constantly stirred: it is then taken off the fire, and suffered to settle for several hours together: the clarified liquor is now decanted off; eight pounds of tartar are poured upon the residue; it is boiled for half an hour, and then mixed with the clarified liquor before poured off from it; the operation is finished by putting the residue upon a filter, and pouring hot water upon it. These lixivia are next reduced all to two pounds by evaporation; a little resin is separated: when the evaporated liquor is cooled, a quantity of muriatic acid is dropped upon it, till it cease to produce a precipitate, and the liquor take a discernible acid taste: the salt of benzoin is then precipitated in powder. It is to be edulcorated on the filter: when it is wanted in crystals, it is dissolved in five or six times its weight of boiling water; it is then filtrated through a cloth, and the solution slowly cooled; the salt is deposited in oblong compressed prisms. In this process the lime absorbs the benzoic acid, and forms with it calcareous benzoate, which is very soluble; and the resin is separated from that salt, which has but very little affinity with it. The muriatic acid which attracts lime with more force than the benzoic acid, seizes that earth, and separates the vegetable acid. The liquor, when reduced to two pounds by evaporation, is no longer sufficient to maintain the acid in solution, and it is therefore almost all deposited. Calcareous benzoate has not the smell of benzoin; but as soon as the benzoin is separated by the muriatic acid, it takes that lively smell which is peculiar to this balsamic substance. By this process Scheele obtained 12 or 14 drachms of benzoic acid from the pound of benzoin; whereas sublimation affords

affords only 9 or 10. He farther informs us, that the purification of this salt by hot water and by crystallization, causes a great quantity of it to be lost, and is by no means necessary to prepare it for pharmaceutical purposes. In fact, this salt, when properly crystallized, is very difficult to be reduced to powder; and the design of the purification is to separate only about two grains of resin from the pound of benzoin. Lastly, he remarks, that the filtration of this acid dissolved in water, can be effected only through a linen cloth. The salt being separated quickly, as the liquor cools, stops up the pores of paper, so that the filtration cannot take place.

Since these experiments of Scheele's were made known to the world, M. Lichtenstein has published in Germany some observations on the benzoic acid; in which he asserts, that sublimation affords more of this acid than the process by lime water: but I agree with Scheele and Morveau, in thinking that this can be said only of the purified acid.

The purified benzoic acid has a taste somewhat sour, pungent, hot, and acrid; its smell is only a little aromatic; it communicates an high red colour to the tincture of turnsol.

Heat, while it volatilizes this acid, increases its bulk amazingly. When exposed in a silver ladle to the heat produced by the blow-pipe, it becomes liquid, as has been observed by M. Lichtenstein, and evaporates without inflammation. When suffered to cool, it forms a solid crust, which exhibits on its surface some marks of crystallization in divergent radii. It does not burn with flame, unless when in contact with bodies that are burning with a strong flame. Burning coal only sublimates it rapidly.

Air

Air appears to have no power of acting on this acid; for after being preserved 20 years in a glass vessel, a quantity of it was still very pure, and had lost nothing of its weight: it loses its smell indeed; but that it regains by heat.

The benzoic acid is scarce soluble in cold water. It appears from the experiments of Messrs Wenzel and Lichtenstein, that 480 grains of cold water dissolve no more than one grain of this acid; but the same quantity of boiling water dissolves 20 grains of it; 19 of which are separated by cooling. Bergman says, that boiling water dissolves $\frac{1}{4}$ of its own weight, and that water of a moderate temperature dissolves nearly $\frac{1}{100}$ part.

The benzoic acid combines with all earthy and alkaline bases, forming with them benzoates of aluminous earth, barytes, magnesia, lime, potash, soda, and ammoniac. We know not the particular characteristic properties of each of these combinations, nor the different affinities of the acid with each of these bases. M. Lichtenstein asserts, that it prefers the fixed alkalis, and even ammoniac, to aluminous, magnesian, or calcareous, earth; but a great many more experiments are necessary to determine exactly the order of these affinities: And these are the more necessary, because Bergman has given a different account of them. According to him, lime separates the alkaline bases, and barytes separates lime: it disengages carbonic acid from all of these bases.

The concentrated sulphuric acid dissolves it easily without either noise or heat, according to the same chemist; but passes in consequence of effecting this solution into the state of sulphureous acid; the benzoic acid may be separated from it unaltered by water.

The nitric acid likewise dissolves it, and gives it up
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in the same manner to water without alteration. M. de Morveau has caused these two bodies to re-act on each other with additional force by the application of heat. The nitrous gas was not disengaged till the end of the operation; and the benzoic acid was separated without loss, and without alteration. M. Hermstadt, however, says, that when the concentrated nitrous acid is employed, the benzoic acid becomes fluid, and more fixed in its nature, and loses the characteristics of the tartareous or oxalic acid; but new researches are necessary to establish the truth of this result, to which little confidence can at present be given. That which appears to be most certain concerning this acid is, that it differs in its nature and properties from all other vegetable acids, and retains in it an essential oil, to which it owes its smell, volatility, combustibility, and solubility, in alcohol.

C H A P.

C H A P. VI.

Of Vegetable Acids, partly saturated with Potash, and of the same Acids pure.

IN the fourth chapter, we mentioned a particular class of vegetable acids; which, we said, were in part combined with potash. We know of two acids of this character, the acid of tartar, and the acid of sorrel. We call these acids which are partly neutralized, *acidulæ*; the one is the tartareous, the other the oxalic.

§ I. *Of the Tartareous Acidula, or Tartar, and of the pure Tartareous Acid.*

THE tartar sold in the shops is an essential acid salt combined with a portion of potash and of oil, which is deposited on the sides of hogsheds containing wine, during the insensible fermentation of the wine. It is not, as some chemists have thought, a product

duct of vinous fermentation; for Rouelle the younger has found it fully formed in must and in verjuice. Many other chemists have since found it fully formed in various fruits.

It is in the form of irregular plates, arranged in strata, often full of brilliant crystals, and of an acid vinous taste. It is distinguished into white and red tartar; the latter of which differs from the former only in containing a greater quantity of colouring extractive matter.

Crude tartar, when exposed to fire in close vessels, affords a reddish acid phlegm, an oil that is at first light, but afterwards ponderous, coloured, and empyreumatic, a little ammoniac, and a great quantity of carbonic acid, which Hales, Boerhaave, and many other chemists have taken for air. There remains a coal which contains a good deal of carbonate of potash, and is easily incinerated. By the combustion and incineration of tartar, fixed alkali is obtained in a state of considerable purity. For this end, the tartar reduced to powder is put into rolls of paper steeped in water; they are then put into a furnace between two layers of coal; the coal is kindled, and the tartar is then burnt and calcined: when the fire is extinguished, the rolls are taken out, and are found to retain their form; the matter which they contain is lixiviated with cold distilled water: This lixivium is filtered, and evaporated to a pellicle; it is suffered to cool, in order to separate from it the sulphate of potash, which is formed by rest; the water is decanted from above this salt, and it is evaporated and crystallized anew, till it cease to yield sulphate of potash; it is then evaporated to dryness, and by this means affords potash, partly caustic and partly combined with carbonic acid.

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It is very difficult to dissolve tartar in water; for an ounce of water, 65 degrees above the freezing point, dissolves only four grains of tartar. As it contains a good deal of oily colouring matter, it is purified by solution and crystallization at Aniane and Calvisson, in the neighbourhood of Montpellier. Doctor Fizes favoured the public with an account of this purification, in a Memoir printed among the Memoirs of the Academy for the year 1725.

The tartar is boiled in water; the boiling solution is filtrated; as it cools it becomes turbid, and deposites irregular crystals, which form a paste. This paste is boiled in copper vessels with water, in which there is a mixture of clayey earth, which comes from the village of Merviel, two leagues distant from Montpellier. A froth gathers on the surface of the liquor, which is carefully skimmed off, and is succeeded by a saline pellicle. The fire is then abated; and the pellicle being broken, mixes with the crystals which are precipitated from the solution: these crystals are washed with water, to purify them entirely from a mixture of earth with which they are contaminated, and sold under the name of *cream* or *crystals of tartar*; the only difference between the cream and the crystals being, that the cream is crystallized on the surface, whereas the crystals are deposited at the bottom of the liquor. The white clay appears to serve the purpose of separating from the tartar the superfluous oily and extractive matter, which it contains.

At Venice, tartar is purified in a way somewhat different from this, according to M. Desmaret's account. The salt is reduced to powder, and dissolved in boiling water; it is suffered to deposite any impure matters which it contains; and these are carefully taken out: the liquor

then affords crystals by rest and cooling. These crystals are again dissolved in water, which is exposed to a gentle heat: when this new solution is heated to ebullition, beaten whites of eggs and ashes, previously passed through a sieve, are put into it. This mixture of ashes is repeated 14 or 15 times; the scum produced by the effervescence of the liquor is taken off; and it is then suffered to settle. A pretty white pellicle, and saline crystals of the same colour, are soon formed: the water is then decanted off, and the salt dried. By this method the nature of the tartareous acidulum is in some degree altered, and a part of it is changed into tartarite of potash. The cream of tartar, or purified tartar of Montpellier, must be the subject of our examination, in order that we may understand the nature of the pure tartareous *acidulum*.

The tartareous acidulum, when very pure, is crystallized, but in an irregular manner. Its taste is sour, and not so vinous as that of crude tartar. When it is put on a burning coal, it diffuses a good deal of smoke of a pungent empyreumatic smell; and becomes black and carbonaceous. When this substance is submitted to distillation in an earthen retort, with a balloon terminating in a tube, entering a bell-glass full of water, it affords, if the fire be gradually applied to it, a phlegm, which is at first a little coloured, and somewhat acid: there passes after this an acid which is stronger and of a deeper colour; an oil which by degrees acquires colour and consistency, and has an empyreumatic smell; ammoniacal carbonate; and a large quantity of carbonic acid. In the retort there remains a good deal of coal, which, when lixiviated without incineration, affords a large proportion of potash. All of these products may be rectified by a new distillation at a moderate

derate fire. The phlegm passes almost colourless; the oil, by this rectification, becomes very white and volatile; the ammoniac is in part combined with the acid, and can only be obtained separate and pure by distilling the last portions of the phlegm with an addition of potash. With respect to the coal; the potash which it contains is not produced in the course of the operation, as has been thought by some chemists not well acquainted with the nature of *cream of tartar*; but exists in it ready formed before the operation. The production of the ammoniac is owing to the re-action of this alkali on the oil. A still greater quantity of the volatile salt may be obtained by distilling the oil obtained from the tartareous acidulum upon the coal which it leaves, when analysed in the retort. The proximate cause of the formation of the ammoniac is the combination of the azote of the potash with the hydrogen disengaged from the oil.

The tartareous acidulum suffers no alteration from air. It dissolves in twenty-eight parts of boiling water, and crystallizes by cooling, but in a very confused manner. There is a certain quantity of earth separated from the solution of this salt, which, no doubt, is a part of the earth that was employed to purify it. This solution reddens the tincture of turnsol, and has an acid taste. When left exposed to the air, it becomes turbid, and, after some time, deposits mucilaginous flakes: the acid is then decomposed, and the liquor is, after this, found to contain nothing but carbonate of potash. M. de Machy was the first who observed this decomposition. Messrs Spielman and Corvinus likewise attended to it; but M. Berthollet has observed it with still greater accuracy than any former philosopher. He has observed, that two ounces of tartareous acidulum re-

quire 18 months before they can be entirely decomposed; that these two ounces will afford, in that time, 6½ drachms of carbonate of potash, still oily, and mixed with a small quantity of carbonaceous matter; and that, therefore, the quantity of alkali obtained by this means from the tartareous acidulum is precisely the same which it would afford by combustion and calcination. The alkaline residue which remains after the distillation of this acidulum, and this spontaneous decomposition, prove, therefore, that it contains a proportion of potash, nearly equal to one-fourth of its weight.

We know nothing of the action of siliceous, and very little of the action of aluminous, earth and barytes on the tartareous acidulum. The chemists of the Academy of Dijon have observed, that magnesia forms with this acidulum a soluble salt, liable to be decomposed by fixed alkali; the solution of which affords, by evaporation, in the open air, small prismatic radiated crystals. When exposed to fire, this tartarited magnesia emits bubbles, and is converted into a light coal. M. Poulletier de la Salle obtained from this combination a gelatinous mass, perfectly like a mucilage. These phenomena depend on the particular state of the tartareous acidulum, which is in part saturated in this acidulated vegetable acid.

A number of chemists have given very good descriptions of the manner in which lime and chalk affect the tartareous acidulum. When chalk is cast into a solution of this acidulum, an effervescence takes place, owing to the disengagement of the carbonic acid, and a very copious precipitate is formed; the precipitate is a combination of lime with the tartareous acidulum. The supernatant liquor contains a neutral salt ready formed in the acidulum, or *cream of tartar*, which consists

consists of the pure acid in union with potash : This salt, as we will hereafter see, has been improperly called *soluble tartar*. We are indebted to Rouelle the younger for this analysis of the tartareous acidulum by chalk. It proves, 1. That this substance consists of an excess of oily acid, and a certain quantity of the same acid, united with potash in the state of a neutral salt. 2. That the combination of the tartareous acid with lime, forms a neutral salt which is scarcely soluble. M. Proust has discovered, that calcareous tartarite, distilled in a retort, leaves a residue that takes fire in the air like the pyrophorus.

The tartareous acidulum very readily combines with the different alkalis. Put into a solution of carbonate of potash a quantity of tartareous acidulum in powder; a lively effervescence is produced by the disengagement of the carbonic acid : let acidulum be added till the alkali be saturated ; after boiling this liquor for half an hour, filtrate it, evaporate the filtrated liquor to a pellicle, and suffer it to cool slowly ; oblong square crystals, terminating fopewise at two of their extremities, will be formed. This salt has been called *vegetable salt*, *soluble tartar*, *tartarized tartar* ; but it ought to be called *tartarite of potash*. Its taste is bitter ; when exposed to a strong heat, it becomes carbonaceous : it may be decomposed in a retort ; and it then affords an acid phlegm, oil, a good deal of carbonic acid, and a little ammoniacal carbonate. It attracts, in some degree, the moisture of the atmosphere. It dissolves in four parts of water heated to the temperature of 40° . This solution is decomposed of itself in a few months ; and it then leaves tartareous acidulum in combination with carbonic acid. The mineral acids decompose it, and precipitate the

tartareous acidulum. It is also decomposed by most metallic solutions.

The tartareous acidulum, combined with sulphur, forms the *salt of Seignette*, who was an apothecary of Rochelle, and the first that made up this combination; we give it the name of *tartarite of soda*. To prepare it, put 20 ounces of the acidulum of tartar into four pounds of boiling water; add by degrees very pure crystallized carbonate of soda, till the acidulum be saturated; that is, till the addition of the alkaline salt no longer produce any effervescence. This combination renders the tartareous acidulum soluble. Evaporate the liquor almost to the consistency of syrup; and you then obtain from it by cooling very beautiful and regular crystals, often of a considerable size. These are prisms with six, eight, or ten, unequal sides, with their extremities truncated at right angles. These prisms are generally divided longitudinally into two; and the base on which they stand is marked with two diagonal lines, which cross each other so as to divide it into four triangles. Tartarite of soda, which was at first sold as a secret, and which was discovered at the same time by both Boulduc and Geoffroy in the year 1731, has a bitter taste. It is decomposable by fire, like tartarite of potash; it effloresces in the air, on account of its containing a good deal of water in its crystals: it is almost as soluble as tartarite of potash; and is, like it, decomposable by air, by mineral acids, and by metallic solutions. The mother-water of this salt contains that portion of tartarite of potash which entered into the composition of the tartareous acidulum.

Ammoniac forms with the acidulum of tartar an ammoniacal tartarite, which crystallizes very well by evaporation

poration and cooling. Bucquet says, that its crystals are rhomboidal pyramids. Macquer saw some of them in large prisms, of four, five, or six sides; others swelled in the middle, and terminating in very acute points; and the Academicians of Dijon obtained this salt in parallelepipeds with two alternate sloping sides. This salt, ammoniacal tartarite, has a fresh taste, and is decomposable by fire: it effloresces in the air; it is more soluble in hot than in cold water; and it crystallizes by cooling: lime and the fixed alkalis disengage the ammoniac; the contact of air, mineral acids, and metallic solutions, decompose it. It appears, that when this salt is prepared, the tartarite of potash, which, in union with the tartareous acid, constituted the acidulum, or *cream of tartar*, remains in the mother-water.

Pott and Margraaff have treated the tartareous acidulum with mineral acids; and the latter obtained neutral salts, the same with those which the same acids form with potash: from which he has inferred, that potash exists ready formed in the acidulum. Rouelle the younger, who prosecuted a similar train of experiments, obtained the same results. On throwing a pound of concentrated sulphuric acid on an equal weight of tartareous acidulum in a very fine powder, the mixture becomes hot; the reciprocal action of the two substances may be promoted by the heat of a *balneum marie*, and by stirring them with a spatula of glass: let the heat be continued for ten or twelve hours; the mixture will then become thick like a jelly: then pour upon it two or three ounces of boiling distilled water to render it fluid; and leave it on the *balneum-marie* for about two hours; then take off the fire, and add three pints of boiling distilled water: the solution is

now coloured and opaque ; it contains naked sulphuric acid, a portion of tartareous acidulum, not decomposed, and sulphate of potash. Saturate the excess of sulphuric acid with chalk ; a precipitate of sulphate of lime, with a small portion of tartareous acidulum, is then produced : filtrate the mixture, and evaporate the filtrated liquor ; it now affords so much tartareous acidulum and sulphate of lime, that it is reduced to eighteen or twenty ounces. It is next decanted and evaporated anew ; and it affords, by rest, crystals of sulphate of potash ; which may be thus obtained by repeated evaporation and crystallization till the whole solution be exhausted. This salt is always mixed with a little of the tartareous acidulum, and it burns upon red iron ; but when lixiviated with a sufficient quantity of distilled water, it is dissolved, and the acidulum remains on the bottom of the vessel. This process has been described, and successfully repeated, by M. Bemiard, after Rouelle.

The nitric and the muriatic acids, when treated in the same manner with the tartareous acidulum, afford nitrate and muriate of potash ; which proves incontrovertibly the existence of potash in that substance.

The tartareous acidulum acquires solubility by union with borax and the boracic acid. According to the experiments of M. de Laffone, one part of the latter salt will render four parts of the tartareous acidulum soluble. This mixed solution affords, by evaporation, a greenish gummy salt, which is very acid.

The tartareous acidulum appears to be capable of uniting, without decomposition, with most metallic substances ; as has been shown by M. Monnet and the chemists of the academy of Dijon. But as all of these
combi-

combinations have been but very little examined, we shall here speak only of those in which the acidulum is combined with antimony, mercury, lead, and iron; because these compounds are better known, and much more employed in medicine, than the others.

The combination of the tartareous acidulum with antimony bears the name of *stibiated*, or *antimoniated tartar*. It consists of tartarite of antimony and potash. As it is one of the most valuable medicines which chemistry can supply, we may examine its properties with care. Since the time of Adrian, who first made it known to the world in the year 1631, the method of preparing it has been much varied. All the pharmacopœiæ, as well as the works of chemists, differ, either in respect to the antimonial substances to be employed in this preparation, or in respect to the proportions in which these, the water, and the tartareous acidulum, are to be mixed; or lastly, in respect to the process by which these substances are to be united in stibiated tartar. In Bergman's Dissertation on this medicine, there is an excellent table of the various processes which have been given for the preparation of tartarite of antimony. The sublimated vitreous white oxide, the brown, and the orange-coloured oxide of antimony, have been successively recommended for this purpose. Some have directed to boil these substances with the tartareous acidulum, and a greater or a less proportion of water, for ten or twelve hours; others think half an hour's boiling sufficient: lastly, some writers prefer the evaporation of the filtrated lixivium to dryness; while others would have it to be crystallized, and only the crystals used in medicine. From these various modes of preparation, it happens, that tartarite of antimony can scarce ever be purchased twice precisely of the same strength

strength and nature; and its effects can never be depended upon. Geoffroy, who had examined several sorts of *stibiated tartar* of different degrees of strength, found by analysis, that the weakest *stibiated tartar* contains in the ounce from thirty grains to a dram and eighteen grains of oxide of antimony; that which is moderately emetic, a dram and a half; and that which acts with most energy, no less than two drams and ten grains. The vitreous oxide of antimony has been preferred to other antimonial substances for this preparation; because it dissolves easily by the acidulum of tartar: but this metallic glass may happen to be more or less oxidated; and according as it is more or less oxidated, it will be more or less emetic. However, a transparent vitreous oxide of antimony, levigated and boiled in water with an equal quantity of tartareous acidulum, till the latter be completely saturated, then filtrated and evaporated by a moderate heat; affords by rest and cooling, crystals of antimoniated tartarite; the effects of which, as emetics, may be safely depended upon. Decant the liquor, evaporate it, and you obtain by successive evaporation a new quantity of crystals. The mother-water contains sulphur and tartarite of potash, with a certain quantity of antimoniated alkaline sulphure. When the mixture of tartareous acidulum, vitreous oxide of antimony, and water, which were boiled for the preparation of antimoniated tartarite, is filtrated, there remains on the filtre a seemingly gelatinous, yellow, or brown matter, of which Rouelle has taken notice. According to M. Proust, this jelly, when distilled, affords a very inflammable pyrophorus.

Macquer has proposed the use of white oxide, precipitated from muriate of antimony by water, instead of the

vitreous

vitreous oxide of antimony. That oxide is a violent emetic, and Macquer thought it constant in its effects. Bergman has adopted Macquer's opinion; and in the laboratory of the Academy of Dijon, tartarite of antimony has been since prepared, according to the method of that chemist and M. de Laffone. This preparation has been very successfully employed: the requisite dose is three grains; and this quantity does not affect the stomach or the intestines too violently.

Tartarite of antimony crystallizes in trihædral pyramids. It is very transparent; it is decomposed, and rendered carbonaceous by fire; in the air, it effloresces, takes a dead white colour, and becomes farinaceous. It dissolves in sixty parts of cold water, and in a much smaller proportion of boiling water; it crystallizes by cooling; alkalis and lime decompose it. Calcareous and pure water, in large proportions, are capable of decomposing it; and it should therefore be administered only in distilled water. Alkaline sulphures, and sulphurated hydrogenous gas, produce in its solution a precipitate of a red powder, which is a kind of sulphurated oxide of antimony; and may be employed to ascertain the presence of this salt in any liquor with which it may happen to be mixed. Iron seizes the tartareous acid, and separates the oxide of antimony: stibiated tartar, therefore, should not be prepared in iron vessels. M. Durande, a physician and professor at Dijon, has proposed, that this medicine should be publicly prepared by one uniform process, in the same manner as theriaca. Such a method could not but be very advantageous; the physicians might then all depend on the effects of this medicine. It appears that tartarite of antimony contains that portion of tartarite

tartarite of potash which entered into the composition of the tartareous acidulum; and is therefore a sort of triple salt. The tartareous acid may be combined with mercury in two ways. The one, which is mentioned by M. Monnet, consists in dissolving in boiling water six parts of the tartareous acidulum with one part of oxide of mercury, precipitated from the nitric acid by carbonate of potash. This liquor, by filtration and evaporation, afforded him crystals, which were decomposed by pure water. The second method of combining mercury with the tartareous acidulum, is, by pouring a nitric solution of the metal into a solution of tartarite of potash or soda: a precipitate is thus obtained, which consists of mercurial tartarite; and the nitrate of potash or soda remains dissolved in the liquor.

The tartareous acidulum acts in a sensible manner upon oxide of lead. Rouelle the younger observed, that the tartarite of lead formed in this operation, does not remain dissolved in the liquor; and that the liquor, when evaporated, affords only pure tartarite of potash, which existed, ready formed, in the tartareous acidulum. This is one of the processes which he employed to ascertain the presence of potash in tartar.

Copper and its oxides are easily acted upon by the tartareous acidulum: the result is a beautiful green salt, susceptible of crystallization; but it has not hitherto been carefully examined.

Iron is one of those metals on which the tartareous acidulum acts with the greatest efficacy. A medicine, called *chalybeate tartar*, is prepared by boiling four ounces of levigated iron filings with a pound of white tartar, in twelve pounds of water. When the tartar is dissolved, the liquor is filtrated: it deposits crystals;

stals; and these may be repeatedly obtained by evaporating the mother-water. To prepare *tartarized tincture of Mars*; make a paste of six ounces of iron filings, a pound of white tartar in powder, and a sufficient quantity of water: let this mixture stand undisturbed for twenty-four hours; next, dilute it in twelve pounds of water, and boil the whole for two hours, adding water to supply the room of that which is evaporated; decant off the liquor, filtrate it, and concentrate it to the consistency of a syrup, adding an ounce of alcohol. Rouelle observed, that the potash exists at liberty in this tincture; and that, by treating it with acids, neutral salts are obtained; which demonstrate beyond a doubt the presence of the alkali. There are two other medicines formed by the combination of the tartareous acid with iron; one of these is *soluble martial tartar*, which is a mixture consisting of a pound of *tartarized tincture of Mars*, with four ounces of tartarite of potash, evaporated to dryness. The other is known by the name of *balls of Mars*. These are prepared by putting one part of filings of steel with two parts of white tartar in powder, into a glass vessel, with a certain quantity of brandy: when the liquor is evaporated, pulverize the mass, and add more brandy, which evaporate again as before; repeat this process till the mixture become greasy and tenacious; then make it up into balls.

Crude tartar is of great use in dyeing; hat-makers likewise make use of it.

The several preparations of the tartareous acidulum, which we have here enumerated, are chiefly employed in medicine. The pure tartareous acidulum is thought to be refreshing and antiseptic; in doses of half an ounce, or an ounce, it acts as a gentle purge and puke.

puke. Tartarite both of potash and soda, is frequently taken in doses of a few drams, to assist the action of other purgative medicines. Tartarite of antimony is one of the most useful and most powerful medicines which chemistry affords. This salt is emetic, purgative, diuretic, diaphoretic, or discussive, according to the doses and the circumstances in which it is administered. It often produces even all these effects at once. It may be considered as a powerful alterative, happily qualified to remove obstructions in the viscera, when administered in small and repeated doses. It is given as a vomit in doses of from one to four grains, dissolved in a few glasses of water. A grain of it is sometimes mixed with other medicines to assist their action: lastly, it acts as an alterative when taken, half a grain at a time, diluted in a large proportion of water. M. de Lassone has discovered, that tartarite of antimony is rendered very soluble in water, by mixing with it ammoniacal muriate; and that there results from this mixture a salt of a nature similar to that of ammoniaco-mercurial muriate. This new triple salt cannot but produce very powerful effects on the animal œconomy. *Chalybeated tartar, soluble martial tartar, and the tartarized tincture of Mars,* are employed as tonics and aperitives.

Such are the properties of the native tartareous acidulum, or of the tartareous acid, combined by nature with a certain quantity of potash. It was requisite to examine it with care, as it is so very useful, and so very much employed. But this is not the pure tartareous acid; and it is of no less importance to know the characteristic properties of that substance. M. Retzius has published, in the Memoirs of Stockholm for the year 1770, a process invented by Scheele for extracting and purifying

purifying this acid. Into a solution of two pounds of the tartareous acidulum, in boiling water, put washed chalk, till such time as it cease to produce effervescence, and there be no longer any of the acid in a state of liberty: the quantity requisite is somewhat more than a fourth part of the weight of the acidulum: take out the precipitate of calcareous tartarite which is now formed, place it on a filtre, and wash it with cold water; there are usually thirty-two or thirty-three ounces of it, on account of its containing water. The liquor decanted from above the precipitate, affords by evaporation a quantity of tartarite of potash, which has not been decomposed, equal nearly to half the acidulum employed. Pour upon the calcareous tartarite, in powder, nine and a half ounces of concentrated sulphuric acid, diluted in five pounds five ounces of water; leave this mixture to digest for twelve hours, stirring it from time to time. Decant the liquor from above the sulphate of lime; evaporate it, after ascertaining that it contains no sulphuric acid. In order to that, pour into it a few drops of acetite of lead, or salt of Saturn: if the precipitate thus produced be soluble in vinegar, the lixivium may be inferred to contain no sulphuric acid; but if the precipitate cannot be dissolved in that fermented acid, the lixivium still contains sulphuric acid; which may be separated by digesting it on a certain quantity of calcareous tartarite. Lime may be used instead of chalk, in the process for obtaining the tartareous acid: But as that alkaline earth decomposes the tartarite of potash contained in the tartareous acidulum, the lixivium, when lime is used, contains only alkali instead of tartarite of potash, as in the former process. The use of quicklime in this decomposition affords more of the acid, because

cause lime decomposes twice its weight of tartareous acidulum.

The pure tartareous acidulum obtained in a liquid state by either of these processes, must be evaporated to dryness; then dissolved again, and crystallized either by slow evaporation, according to M. Pæcken; or by cooling the evaporated liquor to the consistency of a clear syrup, according to Bergman. It is obtained in the form of small sharp pointed needles, or minute prisms; the form of which it is scarce possible to determine. Bergman describes them as divergent leaves; M. Retzius compares them to hairs intwined together: They are at first very white; those obtained towards the end of the operation are yellow.

The crystallized tartareous acid melts, fumes, becomes black, and even takes fire, when brought into contact with burning bodies. When distilled, it affords, like the tartareous acidulum, only an acid phlegm, a little oil, and a good deal of gaseous carbonic acid mixed with carbonated hydrogenous gas. The coal which remains contains neither acid nor alkali: which proves that no alkali is formed in consequence of the decomposition of the tartareous acid by fire: this acid, however pure, is always oily. For this reason it is called the *tartareous acid*, and its salts *tartarites*.

It is not liable to alteration in the air: It is much more soluble than the tartareous acidulum: Its taste is very pungent: It reddens the tincture of violets, as well as that of turnsole. It dissolves aluminous earth, and forms with it an aluminous tartarite, which takes only a gummy or mucilaginous consistency by evaporation.

In combination with magnesia, the pure tartareous

ous acid forms a salt; which also, instead of crystallizing, gives a sort of gelatinous matter.

By combination with lime, it affords an almost insoluble salt.

A little potash poured into this solution, precipitates the tartareous acidulum, or *cream of tartar*, in crystals. This discovery, made by Scheele and Bergman, throws more light than any other facts known, on the nature of this vegetable salt. No farther proofs are requisite, as M. de Morveau says, to determine the principles of which the tartareous acidulum consists: we know it to consist of tartarite of potash with excess of acid; but, what is very singular, this acid, naturally very soluble, suddenly loses that property when about half saturated with potash; which, however, is very soluble by itself. This fine experiment also proves, that the tartareous acid is not in any manner altered by Scheele's process; for with about one-fourth or one-third of its own weight of potash, it forms an acidulous salt, similar in nature to the acidulum from which it was obtained. With a greater proportion of potash, it forms a neutral salt, completely saturated and soluble, which is tartarite of potash, or *vegetable salt*.

The tartareous acid with soda forms a crystallizable neutral salt, or tartarite of soda (*salt of Seignette*), which is very pure. With ammoniac it affords a crystallizable ammoniacal tartarite. M. Retzius informs us, that the tartareous acid, when combined with a quantity of ammoniac considerably less than what is required to saturate it, forms a scarce soluble ammoniacal tartareous acidulum, which crystallizes like the common cream of tartar, or tartareous acidulum of potash.

Although the tartareous have not so strong an affinity

nity with the alkalis as the mineral acids; yet these latter salts, when they decompose tartarite of potash or soda, do not completely separate the base, but disengage the tartareous acid into the state of acidulum, of potash, or of soda. The pure tartareous acid does itself partly decompose sulphate, nitrate, and muriate of potash, and separates so much of the alkali as is requisite to bring it into the state of tartareous acidulum, or acidulated tartarite of potash. It does not produce the same effect on nitrate and muriate of potash.

M. Hermstadt asserts, that the tartareous becomes oxalic acid by means of the nitrous acid. Bergman could not effect this change; but he failed probably on account of employing too little of the nitrous acid. As the nitrous acid gives out nitrous gas, when it accomplishes the transmutation of the tartareous acid; the only difference between the tartareous and oxalic acids would appear to be, that the latter contains a greater quantity of oxigene.

The tartareous acid is incapable of acting on silver, gold, or platina; it dissolves their oxides. Its action on copper, lead, and tin, is imperceptible; it dissolves the oxides of these metals, and destroys the red colour of oxide of lead.

It dissolves iron with a very gentle effervescence.

It produces no alteration on antimony in a metallic state, but acts with sufficient force to dissolve its oxides.

It separates lime from the nitric, the muriatic, the acetous, the formic, and the phosphoric, acids.

It precipitates the nitric solution of mercury, the muriatic solution of lead, &c.

Its attractions are represented by Bergman in the following order: lime, barytes, magnesia, potash, soda, ammoniac, aluminous earth; oxide of zinc, iron, manganese, cobalt, nickel, lead, tin, copper, bismuth, antimony, arsenic, silver, mercury, gold, platina, water, and alcohol.

§ II. *Of the Oxalic Acidulum, or Salt of Sorrel, that is sold in commerce, and of the pure Oxalic Acid.*

THE salt of sorrel sold in the shops, or the oxalic acidulum, is extracted in great quantities at Hartz, in Thuringia and Swabia, from the juice of sorrel, called by Linnæus *oxalis acetosella*. An hundred pounds of this plant, cut down in a state of vigorous vegetation, afford, according to M. Savary, fifty pounds of expressed juice; which fifty pounds of juice afford only five ounces of concrete salt by evaporation and crystallization. The salt of sorrel that comes from Switzerland, is distinguished in commerce as the most beautiful and the whitest: that from Forets in Thuringia is dirty and yellowish.

The juice of sorrel has been long known to afford a neutral salt by evaporation. Duclos mentions it in the Memoirs of the Academy for 1668; Juncker likewise speaks of it. Boerhaave, who compares this salt to tartar, has given a very accurate description of the process for obtaining it. M. Margraaf discovered, that potash entered into the oxalic, as well as into the tartareous acidulum. But the nature of this salt was by no means exactly known, till the experiments of

Messrs Savary, Wenzel, Wiegleb, Scheele, and Bergman, were communicated to the world.

The oxalic acidulum exists in small white crystals, opaque, and needled or lamellated. Their form has not been yet fully ascertained; although Capeller and Ledermuller have described them as they appeared through the microscope. M. de Lisle represents them as very oblong parallelopipeds. They consist of collections of long thin leaves, joining at one end, but separate at the other. The taste of this salt is sour, poignant, and at the same time bitter. It communicates a deep red colour to tincture of turnsole and blue paper. Four hundred and eighty grains of this acidulum, distilled in a retort by a fire, the heat of which was properly regulated, afforded M. Wiegleb one hundred and fifty grains of phlegm strongly acid, without either smell or colour. There remained one hundred and sixty grains of grey salt, from which one hundred and fifty-six grains of vegetable alkali were obtained. About four grains of concrete acid salt were likewise sublimed into the neck of the retort: not a drop of oil passed. In this process of distillation there were one hundred and sixty-six grains of loss. But as M. Wiegleb does not mention what elastic fluids were disengaged in this analysis, the loss was probably owing to the disengagement of water in vapours, and of carbonic acid gas mixed with a little hydrogenous gas and carbonaceous matter. By comparing this analysis with that of the tartareous acid, we perceive the oxalic acidulum to be less oily than the other. The liquid acid, therefore, obtained by this distillation, is pure oxalic acid; whereas the tartareous acidulum, when treated with fire, affords an altered acid, different in nature from the tartareous acid, which we call the *pyro-tartareous*

tartareous acid. It is because the acid of forrel contains so little oil, that we call it the *oxalic acidulum* and *acid*; while to the more oily acid of tartar, the rules of our methodical nomenclature require us to give the name of the *tartareous acid*.

The oxalic acidulum, when pure, suffers no alteration by exposure to air; it is more soluble than the tartareous acidulum. According to M. Wiegleb, a drachm of oxalic acidulum from Switzerland requires to dissolve it only six drachms of boiling water; but though other six drachms of boiling water be added, it is entirely precipitated by cooling. According to M. Wenzel, it is even much more soluble than M. Wiegleb represents it; for he found, by experiment, nine hundred and sixty parts of boiling water to take up six hundred and seventy-five parts of this salt: but its solubility varies, according as it is more or less acid; which again depends on the quality of the plant from which it is extracted.

The oxalic acidulum combines with barytes, magnesia, soda, ammoniac, with which it forms triple salt (or *trisules*.) Lime decomposes, by detaching its acid, both that part which is in a state of liberty, and that which is in combination with the potash. One hundred grains of chalk decompose one hundred and thirty-seven grains of the oxalic acidulum. The precipitate of calcareous oxalate that is deposited, weighs one hundred and seventy-five grains; the supernatant liquor affords by evaporation thirty-two grains of carbonate of potash. This process cannot be used in preparing the pure oxalic acid, though the tartareous acid be obtained pure by it: for calcareous oxalate is not decomposable by sulphuric acid, like calcareous tartarite: on the contrary, the oxalic acid has so strong

an affinity with lime, that it attracts this earth from all other acids; and one certain test of the purity of the oxalic acidulum, or salt of sorrel, is, to pour a solution of it into water impregnated with calcareous sulphate: when the acidulum has been really extracted from sorrel, it produces in the water a copious precipitate.

The sulphuric acid contributes to the disengagement of the oxalic acid from the acidulum by means of heat, according to M. Wiegleb. The nitric acid decomposes the acidulum, and separates the alkali; but it has much more difficulty to accomplish this on the oxalic than on the tartareous acidulum, according to Margraaff's experiments.

The oxalic acidulum acts upon iron, zinc, tin, antimony, and lead. It dissolves the oxides of all the other metals, forming with them triple crystallizable salts, which are not deliquescent, and in which the potash always remains in union with the acid; it precipitates the nitric solutions of mercury and silver. M. Bayen, by evaporating the supernatant liquor from above these precipitates, obtained nitrate of potash, and thus established more certainly the existence of alkali in this acidulum.

To prepare the oxalic acid by separating the potash of the acidulum, distillation, as we have already seen, may be employed: but this process affords only a small quantity; and that which Scheele has recommended, being easier performed, and more certain in its results, is therefore preferable. Saturate the oxalic acid with ammoniac; pour into this triple solution, consisting of oxalic acid, with ammoniac and potash, a quantity of barytic nitrate. A precipitate of barytic oxalate is thus produced, and the nitric acid retains the potash
and

and ammoniac: After washing the barytic oxalate, decompose it with sulphuric acid. The sulphate of barytes that is now formed, remains insoluble at the bottom of the liquor. Decant off the liquor; separate the portion of sulphuric acid which may still be contained in it by barytic oxalate, dissolved in boiling water; and when it ceases to afford a precipitate, the liquid may be considered as containing pure oxalic acid, and decanted off from above the precipitate. It is next to be evaporated with proper care; and it now affords the salt, by cooling, in quadrilateral prisms, with their sides alternately broad and narrow, and terminating in dihædral summits. These crystals are often in the form of square or rhomboidal plates.

This concrete acid has a very strong sour taste; seven grains communicate a sensible acidity to two pounds of water. It reddens all blue vegetable colours. A grain of this salt communicates to 3600 grains of water the property of reddening paper tinctured with turnsole.

The concrete oxalic acid, when exposed to a moderate fire, becomes dry, and is covered over with a thick crust; it is in a short time reduced to powder, and loses $\frac{3}{4}$ of its weight. When distilled in a retort, by a stronger fire, which must not, however, be violent, it liquefies, becomes brown with ebullition, affords an acidulated phlegm, and is partly sublimated, without alteration. There is at the same time disengaged from it a gas mixed with carbonic acid, and hydrogenous gas. When exposed to a violent heat, it affords more gas, less sublimated concrete acid, and more acidulated phlegm, that is not liable to crystallization; at the bottom of the retort there remains only a grey or

brown mass, amounting to one-fiftieth part of the acid employed. When put upon a coal burning in the air, it emits a very acrid white smoke, which irritates the lungs in a very lively manner: the residue which it leaves is white, without any mixture of carbonaceous matter. Such is the result of the decomposition of the oxalic acid by fire that was observed by Bergman. The Abbé Fontana has obtained near double the quantity of gas; but that, as we have already shown, depends on his having applied a stronger heat, with a view to effect a thorough decomposition of the acid.

When exposed to moist air, the concrete oxalic acid remains deliquescent, but in hot air it rather becomes dry. Cold water dissolves a quantity of it equal to one-half of its own weight. When crystals of this acid are cast into cold water, a faint noise is heard, which must be produced by a sudden breaking of their particles. The specific gravity of this cold solution is 1.0593, according to M. de Morveau. No acid vapour rises with the water of the solution when evaporated, not even by ebullition. Boiling water dissolves a quantity of this concrete acid salt equal to itself in weight: One half is precipitated in crystals by cooling.

The oxalic acid dissolves aluminous earth. This solution affords, by evaporation, a yellowish mass, transparent, soft, and astringent; which attracts moisture from the atmosphere, and reddens turnsole. This salt swells in the fire: it then loses its acid, and the aluminous earth remains a little coloured. It is decomposable by mineral acids.

In combination with barytes, it forms a scarce soluble salt; which, with an excess of the acid, affords angular crystals. Hot water, by depriving them of
that

that excess, renders them opaque, pulverulent, and insoluble.

With magnesia, it affords a white salt in powder, which is decomposable by the fluoric acid and barytes.

The oxalic acid, saturated with lime, forms a salt insoluble in water, pulverulent, and not decomposable by fire; for so strong is the affinity between this acid and lime, that it detaches this base from every other acid. On account of this property Bergman has proposed the use of the oxalic acid for ascertaining the presence and the proportion of lime in mineral waters, or in any combination with other acids. Calcareous oxalate gives a green tinge to syrup of violets.

The oxalic acid combines with potash; and the neutral salt, with an excess of either of the two principles, is susceptible of crystallization. Oxalate of potash is very soluble in water, and decomposable by the action of fire and of mineral acids. Pure oxalate acid, added in drops to a solution of this salt, soon produces a precipitate, which appears to be oxalic acidulum, the same as the common *salt of sorrel*.

With two-thirds of soda the oxalic acid forms a salt which is scarce soluble, but dissolves best in hot water, and turns syrup of violets green. An excess of the acid forms acidulous oxalate of soda, which is scarce soluble.

With ammoniac, the oxalic acid affords ammoniacal oxalate, which crystallizes, by slow evaporation, into quadrilateral prisms. By fire this salt is decomposed; and then it yields ammoniacal carbonate, formed by the destruction of the oxalic acidulum. An excess of the acid poured into a solution of this salt, precipitates
from

from it an ammoniacal oxalic acidulum, in crystals much less soluble in water than the pure neutral salt.

The oxalic acid is soluble in mineral acids. It im-
browns the concentrated sulphuric acid; it is decom-
posed by the nitrous acid, and reduced into carbonic acid
in consequence of the decomposition. This acid gene-
rally combines much easier with metallic oxides than
with the metals themselves.

1. With oxide of arsenic, it forms prismatic crystals,
very fusible, very volatile, and decomposable by heat.

2. With oxide of cobalt, a pulverised salt, of a bright
rose colour, and scarce soluble.

3. With oxide of bismuth, a white salt in powder,
very little soluble in water.

4. With oxide of antimony, a salt in crystalline
grains.

5. With oxide of nickel, a salt, of a white or green-
ish yellow colour, and scarce soluble.

6. With oxide of manganese, a salt in a white pow-
der, which becomes black in the fire.

7. With zinc, the solution of which is attended with
effervescence, a pulverulent white salt.

8. It dissolves oxide of mercury, and reduces it to a
white powder, which is rendered black by the contact
of light. This acid decomposes mercurial sulphate and
mercurial nitrate.

9. Tin, by its action, is first rendered black, and af-
terwards covered with a white powder. The salt which
it forms with this metal is of an harsh taste. It crystal-
lizes into prisms by evaporation judiciously conducted;
when evaporated by an intense heat, it leaves a trans-
parent mass, resembling horn.

10. It tarnishes lead, but dissolves its oxide better.

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The saturated liquor deposits small crystals, which may also be obtained by pouring oxalic acid into a solution of nitrate or muriate of lead, or into acetite of the same metal.

11. It acts on iron filings; and as there is water decomposed in this solution, there is, of consequence, hydrogenous gas disengaged. Oxalate of iron is stiptic: it affords greenish-yellow prismatic crystals, decomposable by heat.

Yellowish oxide of iron, in combination with this acid, affords a yellow salt, similar to that which is obtained by pouring liquid oxalic acid into a solution of sulphate of iron.

12. It acts on copper, and entirely dissolves the oxides of this metal. The salt thus formed is of a clear blue colour, and scarce soluble. This salt may be likewise obtained by precipitating sulphuric, nitric, muriatic, and acetic solutions of copper with oxalic acid.

13. Oxide of silver precipitated by potash, dissolves in a small proportion in this acid. The best way of obtaining this salt is by precipitating the nitric solution of silver with oxalic acid; a white sediment is produced, scarce soluble in water, and liable to become brown by the contact of light.

14. This acid scarce acts on oxide of gold.

15. Lastly, it dissolves the precipitate of platina produced with soda. This solution is somewhat yellow, and affords crystals of the same colour.

Such are the phenomena of the combinations of the oxalic acid, as described by Bergman.

That celebrated chemist accomplished all these combinations with artificial oxalic acid, prepared from sugar and nitric acid. Sugar, as well as all mucilages,
ex-

extracts, sweet oils, and farina, affords, when treated with nitrous acid, an acid perfectly the same with pure oxalic acid, as has been ascertained by Scheele. All these matters, and even a great many animal substances, as has been discovered by M. Berthollet, contain therefore the radical principle of the oxalic acid, wanting nothing but oxigene to complete the acid.

Bergman was the first who discovered that sugar, treated with nitrous acid, formed a peculiar acid: he gave it the name of the *acid of sugar*, or *saccharine acid*; which it retained for several years, till Scheele showed it to be precisely of the same nature with the oxalic acid, extracted from *salt or sorrel* by the process above described. He showed the identity of these acids, by forming the scarce soluble oxalic acidulum, or *salt of sorrel*, from a combination of a small quantity of soda with the saccharine acid. Here then is a vegetable acid which exists in an acid state in but few vegetable matters, but of which the base is exceedingly copious in those matters, and appears to pass unaltered into animal bodies. In the following chapters, we shall see that this acid is probably, like all other vegetable acids, a compound of hydrogen, carbone, and oxigene; and that the only difference between it and the other vegetable acids is in the proportions of their principles.

The base or radical principle of the oxalic acid appears to exist in greater plenty in insipid matters than in sugar; though it was once believed, that saccharine bodies afforded most of it. From sugar, Bergman obtained only a third part of its weight of oxalic acid: and from wool M. Berthollet has obtained a quantity equal to more than half the weight of the wool.

The

The pure oxalic acid is used no where but in the laboratory; the chief use to which it is there applied, is to ascertain the presence of lime. The oxalic acidulum, or salt of sorrel, is used to efface stains of ink from white stuffs, wood, ivory, &c. on account of its having so strong an affinity with iron; but the pure oxalic acid being more soluble, might be more advantageously used for such purposes.

END OF VOLUME SECOND.



